# Reverse Engineering with Ida Pro

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Federal 2006

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# Administrivia

- Welcome!
- Please turn in your "A" ticket in exchange for a CD and printed notes
  - **WARNING – the CD contains code that will trigger your AV software**

# Administrivia

- Class only wireless (i.e. no internet)
  - Ssid: ctf
  - Wep key: 0xAAAAAAAAAAAAAAAAAAAAAAAAAA
    - i.e. hex key consisting of 26 A's
- Class ftp server
  - 172.16.5.11

# Administrivia

- cygwin users
  - Make sure you have gcc/g++ AND make installed before tomorrow

# Background

- Personal experience
  - 20+ years assembly/C/C++/…
  - 8 years teaching graduate level CS
    - Programming languages
    - Forensics
    - Computer network attack/defense
- Interests
  - Obfuscated code analysis

# Class Background

- Profession
  - Industry?
    - Hardware
    - Software
  - Government?
  - Academic?
- Experience
  - IDA?
  - x86? Other ASM?
  - Windows? Linux?

# Expectations/Goals

- Discover how a program works
  - Build compatible software
- Locate hidden functionality
  - Backdoors etc.
- Search for vulnerabilities in closed source software

# Introduction

- Reverse engineering with Ida
  - Created by Ilfak Guilfanov
  - Premier disassembly tool available today
    - Interactive
    - Many platforms supported
    - Highly extensible

# Basic Disassembly Theory

# Disassembly

- Need the proper tools
- Tools must understand executable file format
  - Unless you are dying to parse the file yourself in a hex editor
- Parse machine language op codes back to their assembly language equivalents
  - Must know when to stop, data vs. code

# Disassemblers vs. Debuggers

- Debuggers by nature are designed to run code
  - All can disassemble if asked to
    - Single functions
    - From IP forward
  - Most don't do batch disassembly
- Disassemblers aren't interested in running code

# Disassemblers

- Two main types
  - Linear sweep
  - Recursive descent
- Output is generally a disassembly listing
  - Can yield extremely large text files
  - Difficult to navigate/change
- Disassembly fails to reveal obfuscated code

# Disassembly Tools

- Linux
  - objdump
    - Provides a lot of info, see man page for switches
      - objdump –d /bin/cat
  - gdb
    - Can generate disassembly listings but they are cumbersome
- Windows
  - Interactive Disassembler Pro (IdaPro)
    - Understands most executable file formats

# Binary File Formats

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# Common Formats

- Executable and Linkable (ELF) Format
  - Found on Linux/Unix
  - Described in file docs/ELF_Format.pdf on the CD
- Portable Executable (PE) Format
  - Windows
  - Several files in the docs directory on the CD

# Common Elements

- Each format specifies header fields that describe
  - Characteristics of the executable
  - Point to various portions of the executable
  - Import and export fields
  - Debugging information
  - Others

# Essential Information

- Virtual address info
  - Where to load
  - Program entry point
- Relocation information
  - How to modify the memory image if it can't be loaded at its preferred location
- Program section descriptions
  - Where and how large various sections are

# Program Sections

- Many different types
  - Code sections contain the executable portions of the program
    - Often named ".text"
  - Data sections contain various types of statically allocated data
    - Read only data - .rodata
    - Read/write initialized data - .data
    - Read/write un-initialized data - .bss

# Program Sections (cont)

- Import sections
  - Procedure linkage table - .plt
  - Global offset table - .got
  - Import table - .idata
- Other sections
  - Some sections are required only by the linker and are not used at run time

# Ida Pro

# IDA Pro

- Interactive Disassembler Professional
  - http://www.datarescue.com/idabase
- Recursive descent disassembler
- Premier disassembly tool for reverse engineers
  - Handles many families of assembly language
- Interactive manipulation of disassembly listing
- Scripting and plugins
- Runs on Windows and Linux

# IDA Pro Operation

- Load the binary of interest
- IDA builds a database to characterize each byte of the binary
  - All manipulations of the disassembly involve database interactions
- Performs detailed analysis of code
  - Recognizes function boundaries and library calls
  - Recognizes data types for known library calls

# Ida Pro Features

- Graph based display of program flow
- Flowchart display of function flow
- Displays data and code cross references
  - List of all locations that refer to a particular piece of data
  - List of all locations that call a particular function
- Automatic recognition of string constants

# Ida Pro Features

- Hex display option
- Separate strings window
- Separate list of all symbols in the program
- Very nice stack frame displays
- Allows you to assign your own names to code locations/functions
- Allows you to assign your own names to function locals and parameters

# Ida Basics

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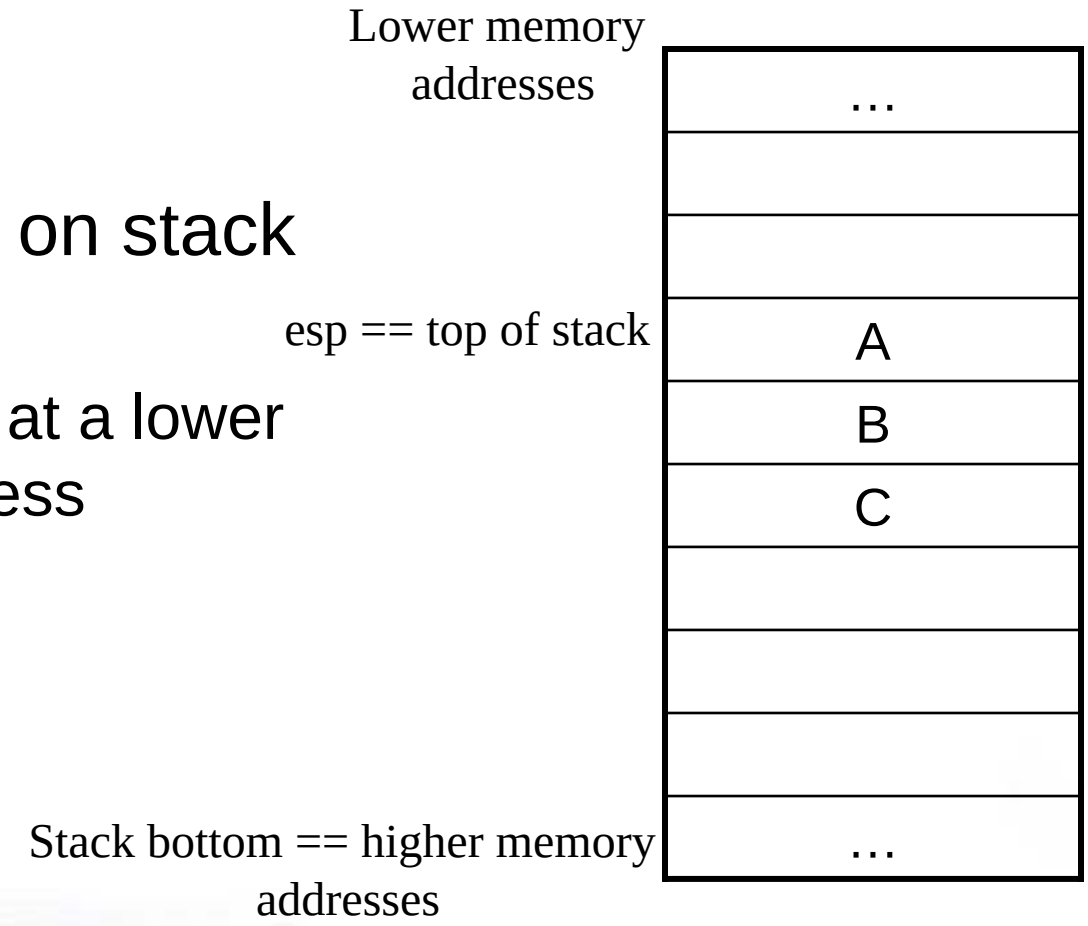
# Assembly Notes

- We will use "intel" syntax throughout
  - MOV  <dest>, <src>
    - This is what IDA produces
    - objdump –d –M intel <file>
    - gdb – set disassembly-flavor intel
  - As opposed to "AT&T" syntax
    - MOV  <src>, <dest>
    - Default for objdump, gdb

# Stack Terminology/Display

- For this class
- A is "above" B on stack to the right
  - Though it lies at a lower memory address



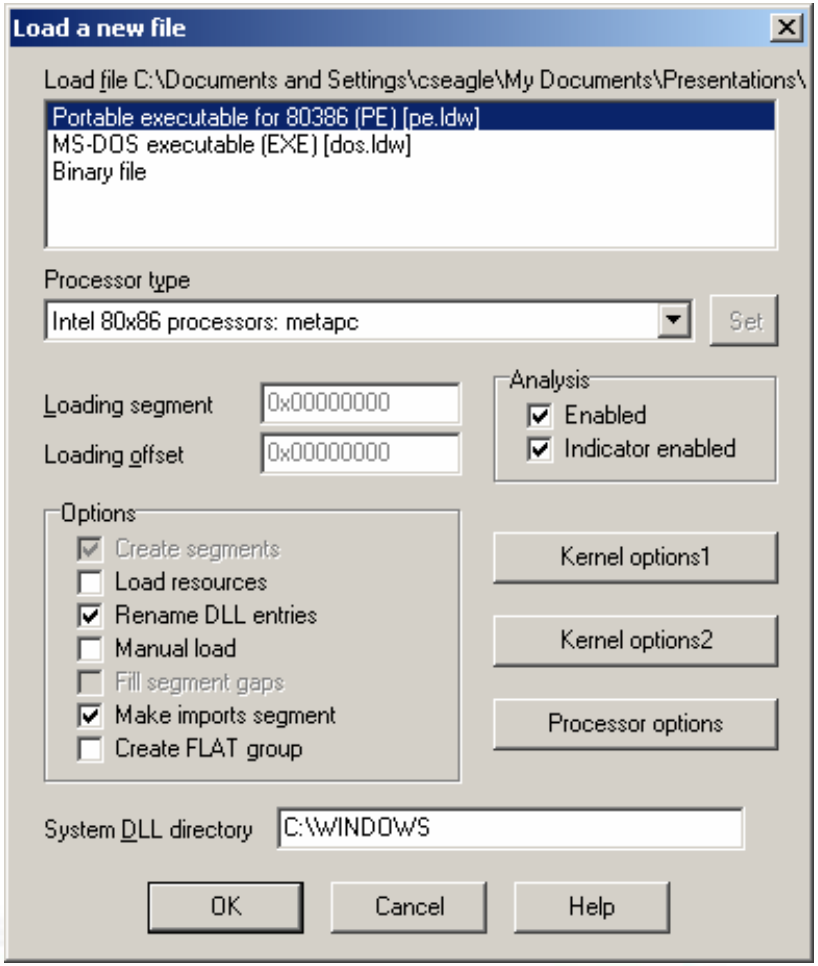
# Using Ida Pro

- Open Ida
- Choose "New" to start a new project or "Previous" to resume previous work
- If "New" selected, navigate to the file you wish to disassemble and open it
- Ida should recognize the file format and start to analyze your file
  - Displays as much info as possible taking symbol tables and debugging info into account

# Basic Ida Walkthrough

- Open the file
  - demos/ asm_code_samples_bor.exe
- Observe file type identification
- Ida analyzes file and opens various analysis windows
- The source code for this file can be found in
  - demos/asm_code_samples.c
  - Open it for comparison with the binary

# Ida Open File Dialog



# Caution

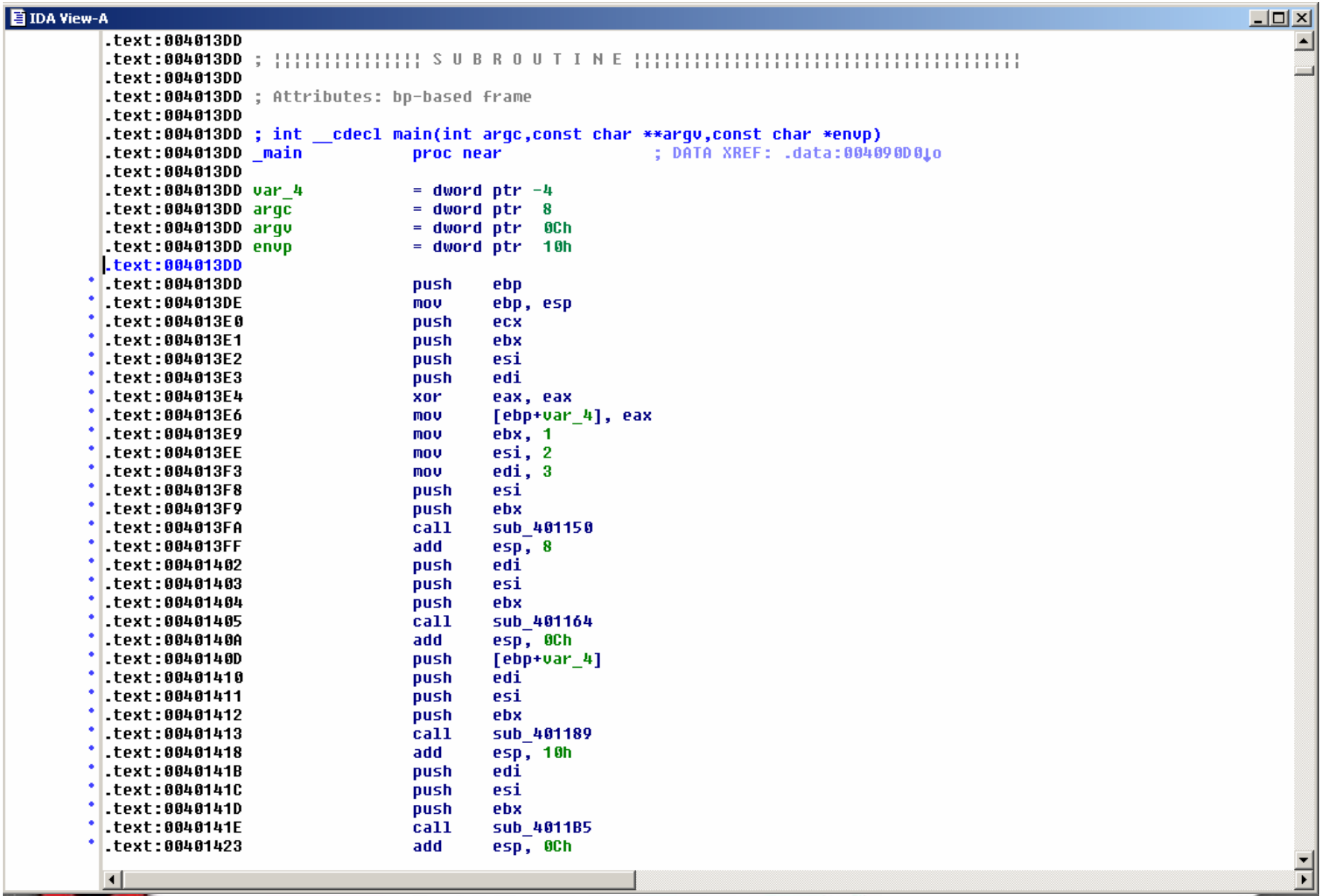
- IDA began life as a DOS application
  - Virtually every action has a hot key sequence
    - Consequently, virtually every key makes something happen
    - THERE IS NO UNDO IN IDA PRO
- Almost all IDA actions are also available via menu items or toolbar buttons

# Ida Navigation

- Double click on a reference to a name and IDA jumps to the named location
  - Names can be
    - Function names
    - Local jump targets within a function
    - Global variable names
- IDA maintains a web-browser-like history list
  - The ESC key acts like a back button
  - There are also forward and backward arrows to move back and forth as well

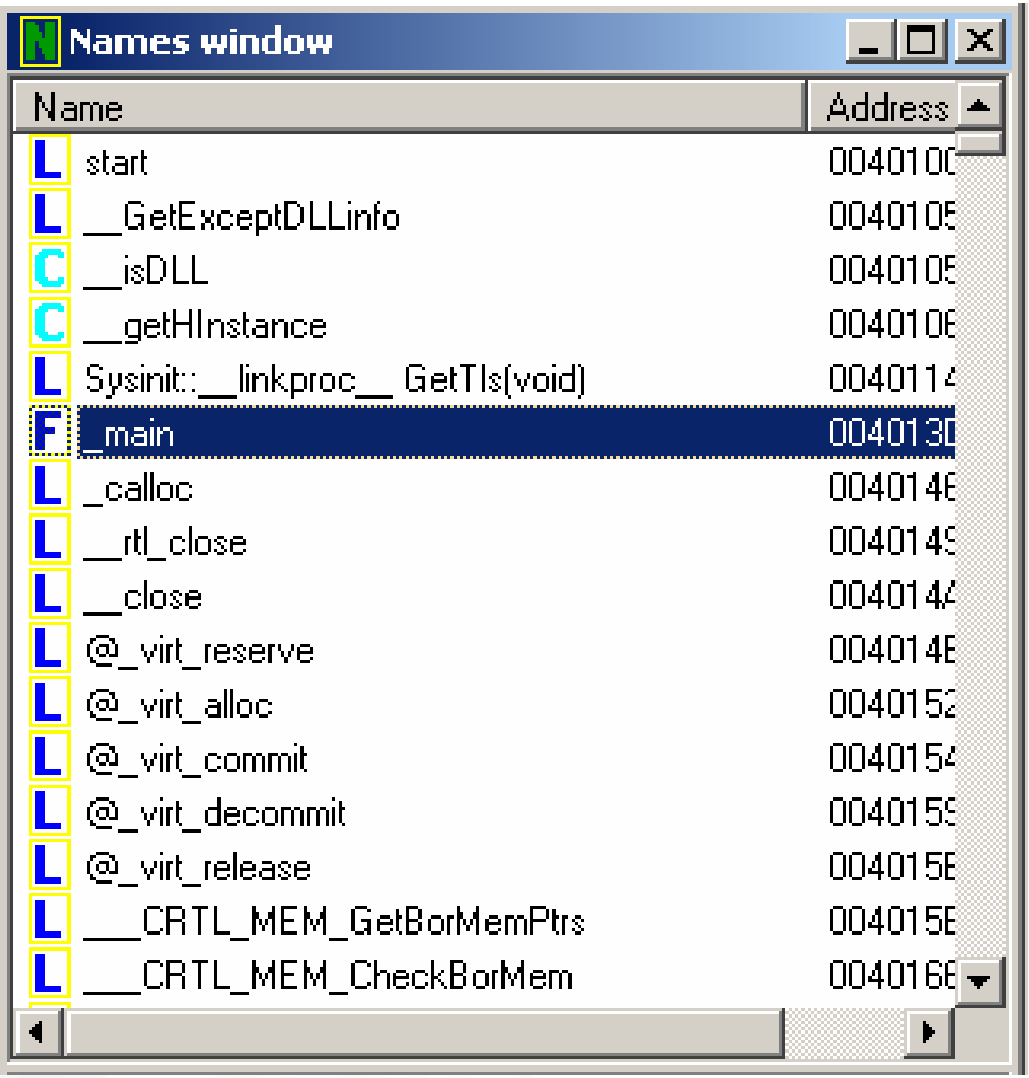
# IDA View Window

- This is the main working window
  - Disassembly view
- Disassembly initially positioned at entry point or main
  - Entry point for programs is generally not main but a location named start or _start
    - Start does program setup before calling main
  - If main is present, Ida will position cursor there



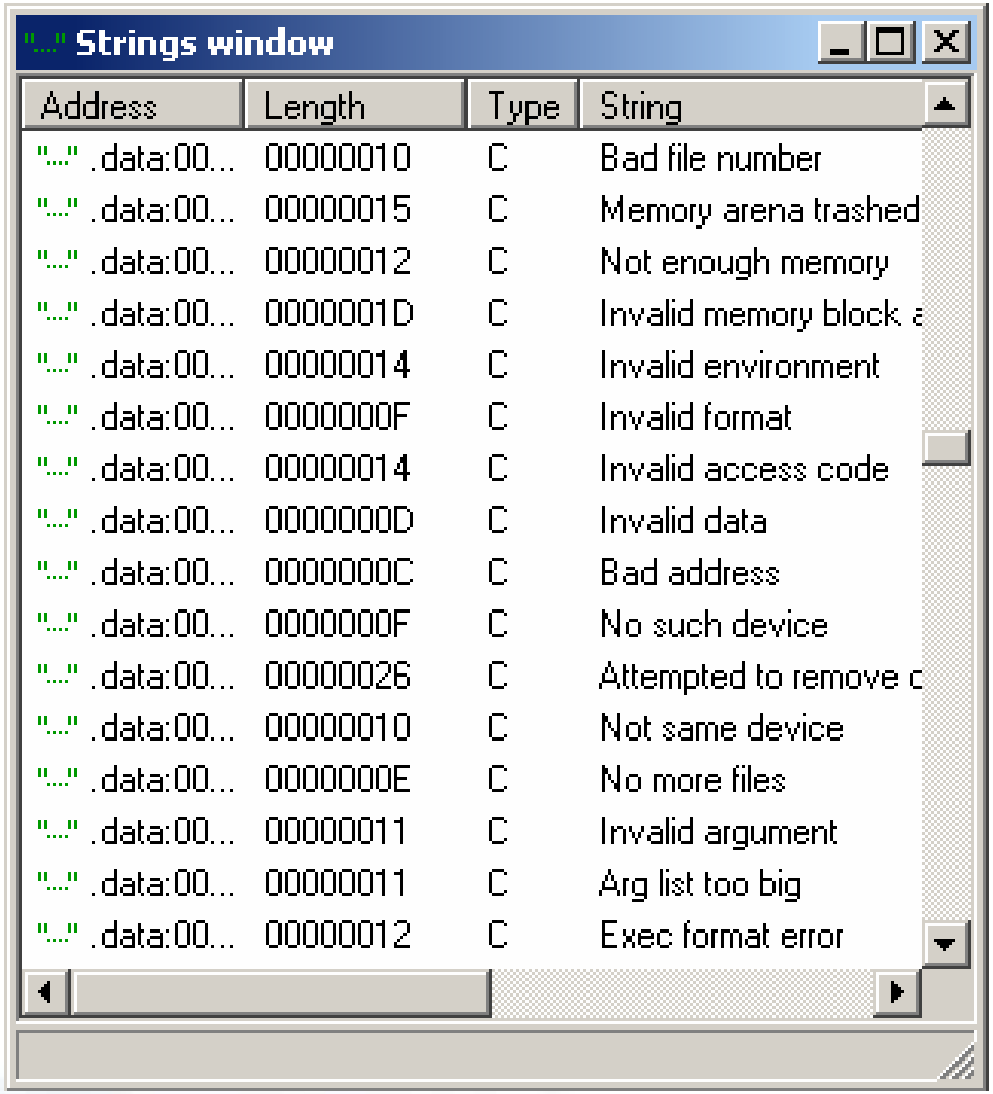
# Names Window

- Lists all known named locations in program
  - Based on imports, exports, and some analysis
  - F is a function
  - L is a library function
  - C is code/instruction
  - A is a string
  - D is defined data
  - I is an imported function
    - Dynamically linked



# Strings Window

- Strings window
  - Complete listing of embedded strings within program
  - Configurable
    - Right click in Strings window and choose setup
    - Can change minimum length or style of string to search for
      - Ida rescans for strings if you change settings



# Ida Interaction

- One of the greatest strengths of Ida is the ability to interact with a disassembly
  - Rather than a static disassembly file generated by a tool such as objdump
- Among other things you can do
  - Renaming
  - Reformatting code-data-code
  - Adding comments
  - Many others

# Renaming in Ida

- Having source code is cheating
  - But useful today so we can see original names used by the programmer
- Compilation is a lossy operation
  - In a binary we are lucky to get functions names
    - Not always the case
  - Never get local variable names

# Ida Names

- Just about anything in Ida can have a name
  - Any address or stack variable
- Ida will assign names based on
  - Symbol table in binary
  - Default generated name
  - User assigned

# Ida Default Names

- sub_xxxx
  - function starting at address xxxx
- loc_xxxx
  - Code at location xxxx that is referenced from elsewhere, generally a branch target
- byte_xxxx, word_xxxx, dword_xxxx
  - Byte, word or dword data at location xxxx

# Changing/Adding Names

- The name of anything can be set or changed
- Edit/Rename, hotkey is ‘n’
- Place the cursor on the item that you wish to rename and press ‘n’
- Opens dialog to rename variable or address

# Example

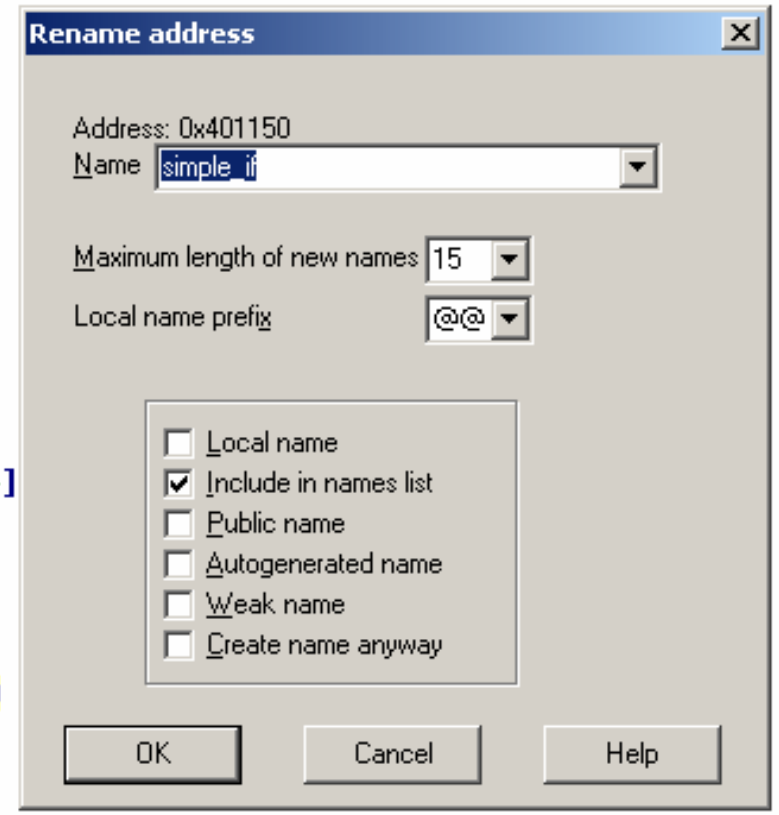
- In the Ida View window, click on sub_401150 at this line:

  .text:004013FA call sub_401150

  – Press ‘n’ to open a rename window
  – This particular window applies to renaming addresses
- Enter the new name ‘simple_if’
- Changing a globally scoped name adds it to the Names window

# Before Renaming

```
.text:004013DD ; int __cdecl main(int argc,const char **argv,const char *envp)
.text:004013DD _main           proc near               ; DATA XREF: .data:004090D0↓o
.text:004013DD
.text:004013DD var_4           = dword ptr -4
.text:004013DD argc            = dword ptr  8
.text:004013DD argv            = dword ptr  0Ch
.text:004013DD envp            = dword ptr  10h
.text:004013DD
.text:004013DD                 push    ebp
.text:004013DE                 mov     ebp, esp
.text:004013E0                 push    ecx
.text:004013E1                 push    ebx
.text:004013E2                 push    esi
.text:004013E3                 push    edi
.text:004013E4                 xor     eax, eax
.text:004013E6                 mov     [ebp+var_4]
.text:004013E9                 mov     ebx, 1
.text:004013EE                 mov     esi, 2
.text:004013F3                 mov     edi, 3
.text:004013F8                 push    esi
.text:004013F9                 push    ebx
.text:004013FA                 call    sub_401150
.text:004013FF                 add     esp, 8
.text:00401402                 push    edi
.text:00401403                 push    esi
.text:00401404                 push    ebx
```



# After Renaming

```
.text:004013DD
.text:004013DD ; int __cdecl main(int argc,const char **argv,cc
.text:004013DD _main            proc near               ; DATA X
.text:004013DD
.text:004013DD var_4            = dword ptr -4
.text:004013DD argc             = dword ptr  8
.text:004013DD argv             = dword ptr  0Ch
.text:004013DD envp             = dword ptr  10h
.text:004013DD
.text:004013DD                  push    ebp
.text:004013DE                  mov     ebp, esp
.text:004013E0                  push    ecx
.text:004013E1                  push    ebx
.text:004013E2                  push    esi
.text:004013E3                  push    edi
.text:004013E4                  xor     eax, eax
.text:004013E6                  mov     [ebp+var_4], eax
.text:004013E9                  mov     ebx, 1
.text:004013EE                  mov     esi, 2
.text:004013F3                  mov     edi, 3
.text:004013F8                  push    esi
.text:004013F9                  push    ebx
.text:004013FA                  call    simple_if
.text:004013FF                  add     esp, 8
.text:00401402                  push    edi
```

# Readability

- Note the improved readability of the code
- The previous name sub_401150 is an example of an Ida default name
  - Not at all descriptive
- When you rename an item, Ida makes the change in all locations that refer to that item

# Navigation

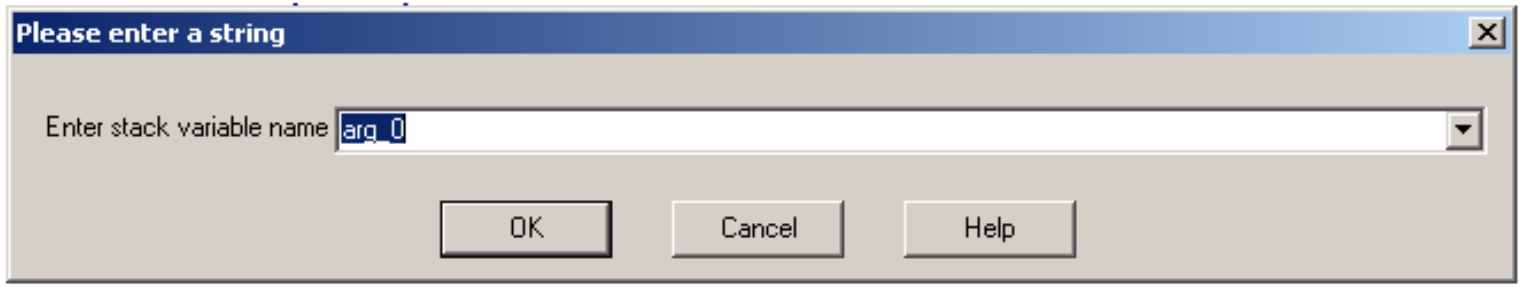
- Double click on ‘simple_if’ to jump to the simple_if function
  - Easy navigation reduces the need for search
  - ESC will take you back
    - Careful with ESC, in every window other than the View window, ESC closes the window
    - Recover windows via the View/Open Subviews menu

# Renaming Variables

- From the source code we can see that simple_if has two arguments, a and b as well as a local variable result
  - Highlight and press n to rename them
- Ida shows two arguments arg_0 and arg_4, but no local variables
  - Ida default names
    - arg_x an argument x bytes below saved eip
    - var_x a local variable x bytes above saved registers

# Renaming a Stack Variable

```
.text:00401150 simple_if       proc near               ; CODE XREF: _main+1D↓p
.text:00401150
.text:00401150 arg_0           = dword ptr  8
.text:00401150 arg_4           = dword ptr  0Ch
.text:00401150
.text:00401150
.text:00401151
.text:00401153
.text:00401156
.text:00401159
.text:0040115B
.text:0040115D
.text:0040115F
.text:00401162
.text:00401162 loc_401162:                             ; CODE XREF: simple_if+D↑j
.text:00401162                 pop     ebp
.text:00401163                 retn
.text:00401163 simple_if       endp
.text:00401163
```



# After Renaming

View-A

```
.text:00401150 simple_if       proc near               ; CODE XREF: _main+1D↓p
.text:00401150
.text:00401150 a               = dword ptr  8
.text:00401150 b               = dword ptr  0Ch
.text:00401150
.text:00401150                 push    ebp
.text:00401151                 mov     ebp, esp
.text:00401153                 mov     ecx, [ebp+b]
.text:00401156                 mov     edx, [ebp+a]
.text:00401159                 xor     eax, eax
.text:0040115B                 cmp     ecx, edx
.text:0040115D                 jge     short loc_401162
.text:0040115F                 lea     eax, [ecx+edx]
.text:00401162
.text:00401162 loc_401162:                             ; CODE XREF: simple_if+D↑j
.text:00401162                 pop     ebp
.text:00401163                 retn
.text:00401163 simple_if       endp
.text:00401163
.text:00401164
```

Note use of a and b here

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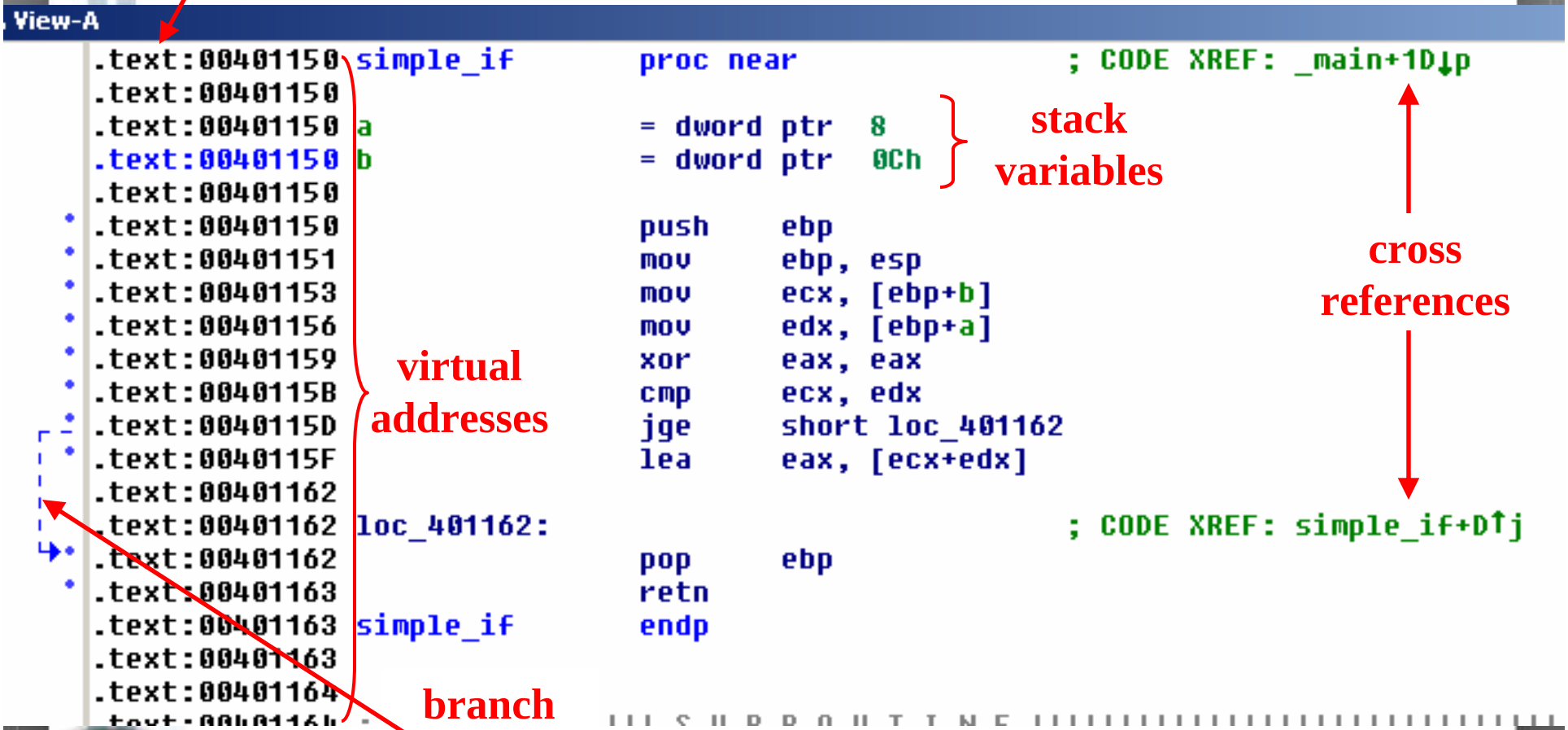
# Ida Display Elements



# Features of Compiled Code

# Assembly Constructs

- It is useful to understand what compiled code looks like
- Makes it easier to understand what the source code probably looked like
- Remember, there are always many ways to translate a given sequence of source code into equivalent assembly

# Parameter Passing

- Dictated by calling conventions utilized by each function
- Tells you how parameters will be accessed by each function
- Tells you how parameters will be passed to each function
- Tells you whether caller or callee will clean up the stack afterwards

# Calling Conventions (i)

- Vary by compiler
  - Visual C++
    - cdecl
      - Push parameters right to left
      - Caller cleans up stack
    - stdcall
      - Push parameters right to left
      - Called function cleans up stack
      - Windows API functions use this calling convention
    - fastcall
      - First two parameters (on the left) go in ECX and EDX
      - Remaining parameters are pushed right to left
    - thiscall
      - For C++ non-static member functions, **this** is placed in ECX

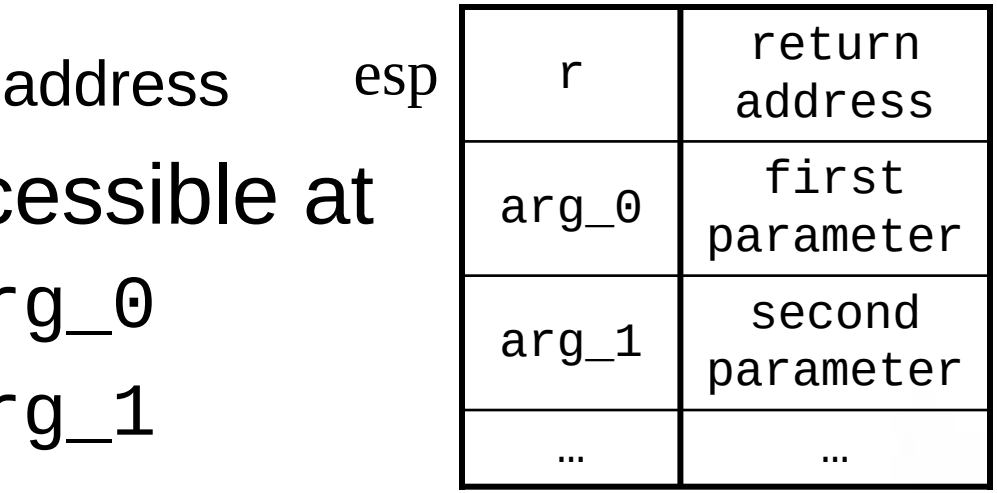
# Calling Conventions (ii)

- gcc
  - Supports cdecl and stdcall
  - cdecl is the default
- g++
  - Pushes "this" as implied first (left most) parameter for non-static member functions
- Others
  - You may see strange things in optimized code

# Parameter Access

- Parameters lie beneath return address
  - `call` was last instruction executed prior to function entry
    - Pushes return address
- Parameters accessible at

```
[esp + 4] ;arg_0
[esp + 8] ;arg_1
…
```



# Local Variables

- Most functions use local variables
  - Locals are instantiated at time of function call
  - Allocated on the stack upon function entry
    - Explicitly decrement esp to allocate
  - Removed from the stack on function exit
    - Various ways to do this

# Local Variable Allocation

```
void foo(int bar, char *str) {
    int x;
    double y;
    char buf[32];
    //function
}
```

- This function requires 44 bytes of space for its locals

# Local Variable Allocation, asm

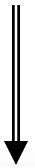
```
foo:
   sub esp, 44   ; allocate locals
   ; function body
   add esp, 44   ; deallocate locals
   ret
```

- Every function is similar
  - First step - allocate locals
  - Last step – deallocate locals

# Stack View

Stack ***frame*** for function foo

| Address | Name | Size |
|---|---|---|
| [esp] | buf | 32 bytes |
| [esp+32] | y | 8 bytes |
| [esp+40] | x | 4 bytes |
| | return | 4 bytes |
| [esp+48] | bar | 4 bytes |
| [esp+52] | str | 4 bytes |



# Stack Frames in Practice

- esp based stack frames are not always practical
- If the function needs to call other functions it must push parameters, altering esp
  - Any change to esp changes the offsets required to access both locals and arguments
- Solution
  - Use a specific register as a fixed "frame pointer"
  - On the x86 this is ebp by convention

# Using ebp as a Frame Pointer

- On entry to a function we must "fix" the frame pointer
  - But there is only one ebp and the function that called us is probably already using it
- Two steps
  - Save the old value of ebp
  - Setup ebp as our frame pointer

# Prologues & Epilogues

- A function prologue is the code required to setup a frame pointer and allocate local variables
- A function epilogue is the code required to restore the caller's frame pointer and deallocate local variables

# Revised foo

```
foo:
   push ebp       ; save callers frame pointer
   mov  ebp, esp  ; setup our frame pointer
   sub  esp, 44   ; allocate locals

; function body

   mov  esp, ebp  ; deallocate locals
   pop  ebp       ; restore caller's fp
   ret
```

# Revised Stack View

Stack ***frame*** for foo

| Address | Name | Size |
|---|---|---|
| [ebp-44] | buf | 32 bytes |
| [ebp-12] | y | 8 bytes |
| [ebp-4] | x | 4 bytes |
| | old ebp | 4 bytes |
| | return | 4 bytes |
| [ebp+8] | bar | 4 bytes |
| [ebp+12] | str | 4 bytes |

← ebp

# Other Considerations

- Where to expect return values?
  - Generally returned in EAX
  - 64 bit values in EDX:EAX

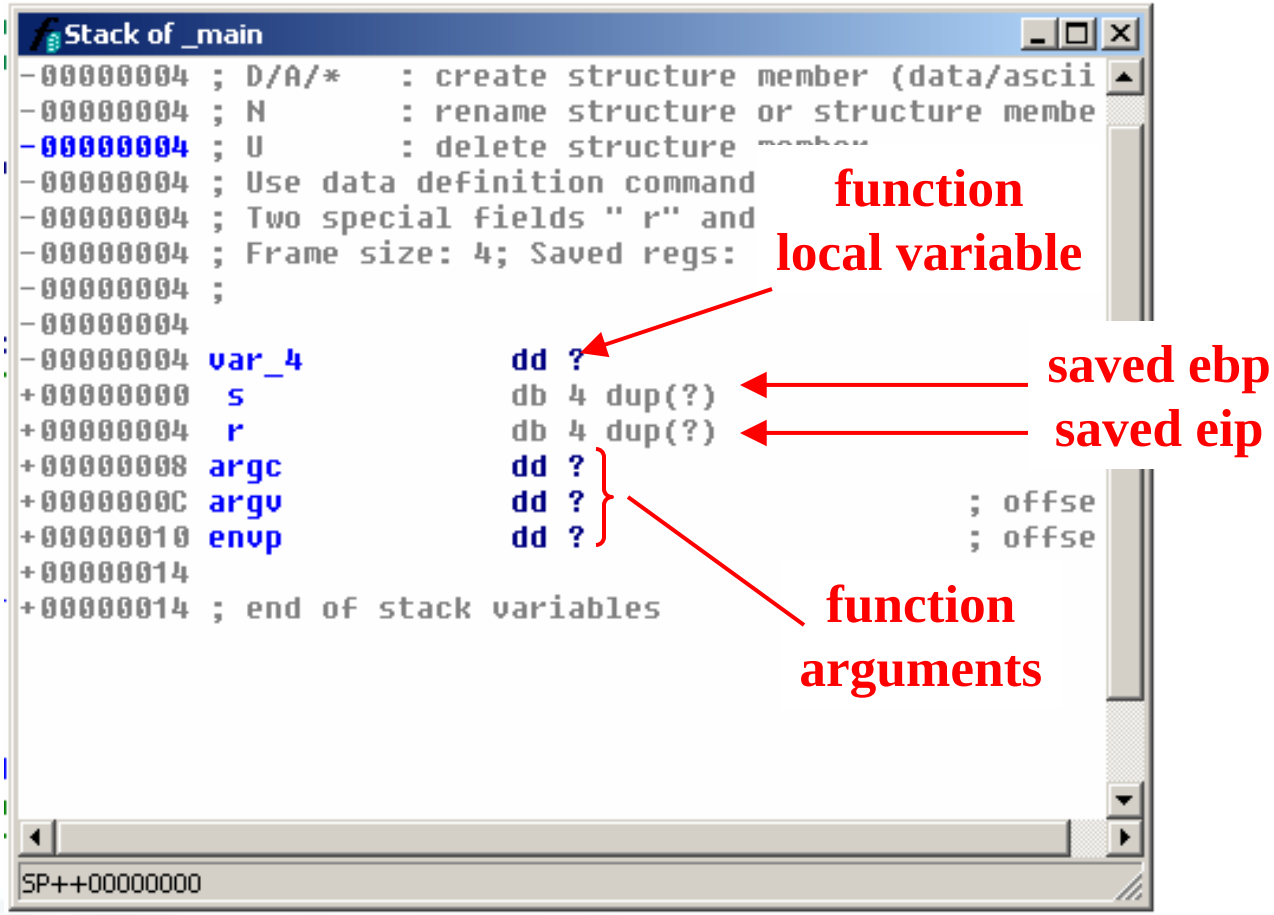
# Ida and Stack Frames

- Ida provides two views of a function's stack frame
  - Compressed view
    - Ida shows arguments and local variables inline with the function disassembly
  - Expanded view
    - By double clicking on any stack variable, you get an expanded view of the stack for a given function

# Example

- In Ida, ESC back to, or otherwise navigate to main
- Double click on ‘argc’ to obtain the expanded stack frame view for main
- Ida determines the runtime layout of each functions stack by analyzing the use of esp and ebp with each function

# Stack Frame of main



# If Statements

- For a simple binary test
  - Compare two values
  - Jump on the inverse of the condition to the first statement beyond the "if body"

```
if (a > b) {
  …
}
```

  - Compare a to b and jump if a <= b

# Simple If Statement (example)

- Conditional test and jump

```
    cmp  eax, ebx       ;if
    jle  endif          ;(eax > ebx) {
         ;if body
                        ;}
endif:
```

# Example

- In Ida, close the stack layout for main by using the ESC key
- Double click on ‘simple_if’ to navigate back to that function
- The disassembled if statement is visible

View-A

```
.text:00401150 simple_if       proc near               ; CODE XREF: _main+1D↓p
.text:00401150
.text:00401150 a               = dword ptr  8
.text:00401150 b               = dword ptr  0Ch
.text:00401150
.text:00401150                 push    ebp
.text:00401151                 mov     ebp, esp
.text:00401153                 mov     ecx, [ebp+b]
.text:00401156                 mov     edx, [ebp+a]
.text:00401159                 xor     eax, eax
.text:0040115B                 cmp     ecx, edx
.text:0040115D                 jge     short loc_401162
.text:0040115F                 lea     eax, [ecx+edx]
.text:00401162
.text:00401162 loc_401162:                             ; CODE XREF: simple_if+D↑j
.text:00401162                 pop     ebp
.text:00401163                 retn
.text:00401163 simple_if       endp
.text:00401163
.text:00401164
```

if body

dashed line indicates conditional branch

solid line indicates unconditional branch

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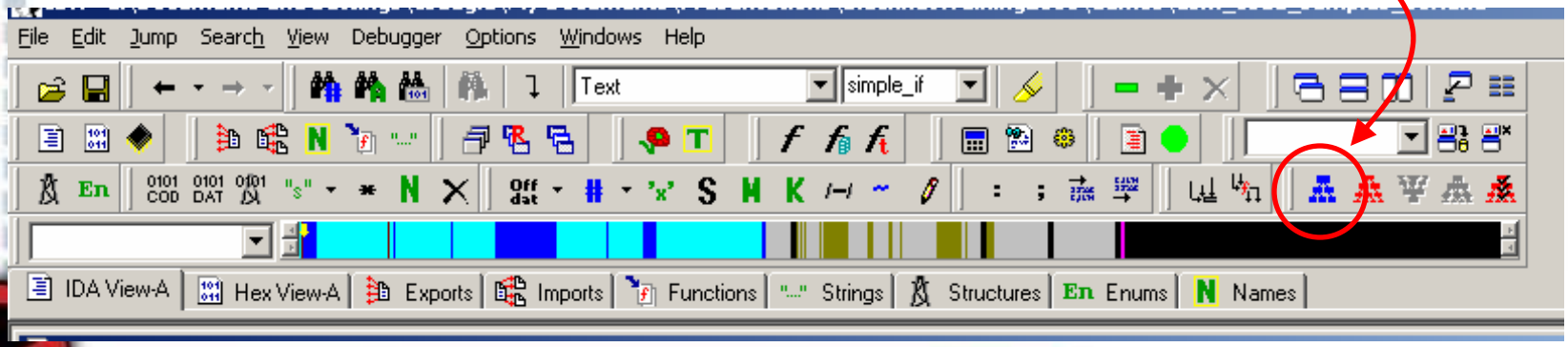
# Ida Flowcharting

- For the graphically oriented, Ida also offers some interesting graphing capabilities
- The first that we will look at is flowcharting
- Available for current function only
- Graphs are not interactive
  - That will change in Ida 5.0

# Flowchart of simple_if

- Position the cursor on any statement of the simple_if function
- Select
  - View/Graphs/Flowchart, or F12, or



# Flowchart Example

- Result is a flowchart that makes it clear that there is some conditionally executed code
  - ESC will close the WinGraph32 window
- This one is easy to interpret because the function is so small
- Complex functions far more difficult

# Compound Condition - OR

- For all but the last condition
  - Test and jump if the condition is true to the first statement of the if body
    - i.e. if any part is true proceed to the body
- For the last term in the OR
  - Test and jump if NOT true to the first statement following the if body
- This implements "short circuit" evaluation

# Compound OR

```
   cmp  eax, ebx          ;if
   jg   body              ;(eax > ebx) ||
   cmp  eax, ecx          ;
   jnz  body              ;(eax != ecx) ||
   cmp  ebx, ecx
   jne  endif             ;(ebx == ecx) {
body:
        ;if body
                          ;}
endif:
```

# Example

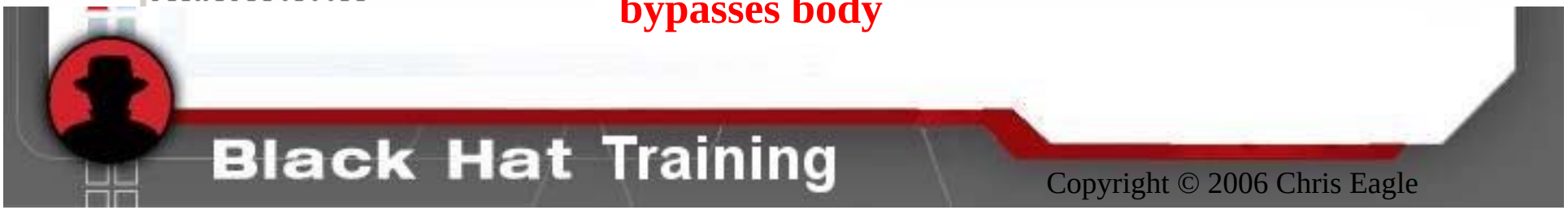
- In Ida, ESC back to or otherwise navigate to main
- The second function main calls is ‘compound_or’
  - Rename it if you like
- Navigate to compound_or

```
.text:00401164 compound_or     proc near               ; CODE XREF: _main+28↓p
.text:00401164
.text:00401164 a               = dword ptr  8
.text:00401164 b               = dword ptr  0Ch
.text:00401164 c               = dword ptr  10h
.text:00401164
.text:00401164                 push    ebp
.text:00401165                 mov     ebp, esp
.text:00401167                 push    ebx
.text:00401168                 mov     ecx, [ebp+c]
.text:0040116B                 mov     edx, [ebp+b]
.text:0040116E                 mov     eax, [ebp+a]
.text:00401171                 xor     ebx, ebx
.text:00401173                 cmp     edx, eax
.text:00401175                 jl      short loc_40117F
.text:00401177                 cmp     ecx, eax
.text:00401179                 jnz     short loc_40117F
.text:0040117B                 cmp     ecx, edx
.text:0040117D                 jnz     short loc_401184
.text:0040117F
.text:0040117F loc_40117F:                             ; CODE XREF: compound_or+11↑j
.text:0040117F                                         ; compound_or+15↑j
.text:0040117F                 lea     ebx, [edx+eax]
.text:00401182                 add     ebx, ecx
.text:00401184
.text:00401184 loc_401184:                             ; CODE XREF: compound_or+19↑j
.text:00401184                 mov     eax, ebx
.text:00401186                 pop     ebx
.text:00401187                 pop     ebp
.text:00401188
.text:00401188 compound_or     endp
.text:00401188
```

Either test true jumps to body

if body

Both tests false bypasses body



# Compound Condition - AND

- For all terms
  - Test for the opposite of the condition and jump to the first statement beyond the if body
    - i.e. if any part is false skip the body
- This implements "short circuit" evaluation

# Compound AND

```
    cmp  eax, ebx          ;if
    jle  endif             ;(eax > ebx) &&
    cmp  ebx, ecx          ;
    jle  endif             ;(ebx > ecx) &&
    cmp  ecx, edx
    jle  endif             ;(ecx > edx) {
body:
         ;if body
                           ;}
endif:
```

# Example

- In Ida, ESC back to main or otherwise navigate to main
- The third function called is ‘compound_and’
  - Rename it if you like
- Navigate to compound_and

```
.text:00401189 compound_and    proc near               ; CODE XREF: _main+36↓p
.text:00401189
.text:00401189 a               = dword ptr  8
.text:00401189 b               = dword ptr  0Ch
.text:00401189 c               = dword ptr  10h
.text:00401189 d               = dword ptr  14h
.text:00401189
.text:00401189                 push    ebp
.text:0040118A                 mov     ebp, esp
.text:0040118C                 push    ebx
.text:0040118D                 push    esi
.tex                           mov     esi, [ebp+d]
.tex                           mov     edx, [ebp+c]
.tex                           mov     eax, [ebp+b]
.tex                           mov     ebx, [ebp+a]
.text:0040119A                 xor     ecx, ecx
.text:0040119C                 cmp     eax, ebx
.text:0040119E                 jge     short loc_4011AF
.text:004011A0                 cmp     edx, eax
.text:004011A2                 jge     short loc_4011AF
.text:004011A4                 cmp     esi, edx
.text:004011A6                 jge     short loc_4011AF
.text:004011A8                 lea     ecx, [eax+ebx]
.text:004011AB                 add     ecx, edx
.text:004011AD                 add     ecx, esi
.text:004011AF
.text:004011AF loc_4011AF:                             ; CODE XREF: compound_and+15↑j
.text:004011AF                                         ; compound_and+19↑j ...
.text:004011AF                 mov     eax, ecx
.text:004011B1                 pop     esi
.text:004011B2                 pop     ebx
.text:004011B3                 pop     ebp
.text:004011B4                 retn
.text:004011B4 compound_and    endp
.text:004011B4
```

Any failure bypasses body

if body

# Commenting in Ida

- Ida allows insertion of several different types of comments
- Comments entered by placing the cursor on the line you wish to comment, then selecting a comment type
  - Edit/Comments menu
- Basic comment hot key is colon i.e. Shift-;

# Commented compound_and

```
.text:00401189 compound_and    proc near               ; CODE XREF: _main+36↓p
.text:00401189
.text:00401189 a               = dword ptr  8
.text:00401189 b               = dword ptr  0Ch
.text:00401189 c               = dword ptr  10h
.text:00401189 d               = dword ptr  14h
.text:00401189
.text:00401189                 push    ebp
.text:0040118A                 mov     ebp, esp
.text:0040118C                 push    ebx
.text:0040118D                 push    esi
.text:0040118E                 mov     esi, [ebp+d]
.text:00401191                 mov     edx, [ebp+c]
.text:00401194                 mov     eax, [ebp+b]
.text:00401197                 mov     ebx, [ebp+a]
.text:0040119A                 xor     ecx, ecx        ; result = 0
.text:0040119C                 cmp     eax, ebx        ; if (a > b)
.text:0040119E                 jge     short loc_4011AF
.text:004011A0                 cmp     edx, eax        ; && (b > c)
.text:004011A2                 jge     short loc_4011AF
.text:004011A4                 cmp     esi, edx        ; && (c > d)
.text:004011A6                 jge     short loc_4011AF
.text:004011A8                 lea     ecx, [eax+ebx]  ; result = b + a
.text:004011AB                 add     ecx, edx        ; result += c
.text:004011AD                 add     ecx, esi        ; result += d
.text:004011AF
.text:004011AF loc_4011AF:                             ; CODE XREF: compound_and+15↑j
.text:004011AF                                         ; compound_and+19↑j ...
.text:004011AF                 mov     eax, ecx        ; return result
.text:004011B1                 pop     esi
.text:004011B2                 pop     ebx
.text:004011B3                 pop     ebp
.text:004011B4                 retn
.text:004011B4 compound_and    endp
```

# If/Else Statement

- All conditional tests that evaluate to false jump to the first statement of the else body
- The last statement of the if body is an unconditional jump past the else body

# Simple If/Else Statement (example)

- Conditional test and jump

```
    cmp  eax, ebx          ;if
    jle  else              ;(eax > ebx) {
         ;if body
    jmp endif              ;}
else:                      ;else {
         ;else body
                           ;}
endif:
```

# Example

- Navigate back to main
- The next function called is named if_else
- Navigate to if_else and create a flow chart
  - The if/else structure is clear from the flow chart
  - Executes code in either case
  - Compare this to the graph for simple_if

# Loops

- Although x86 offers the `loop` instruction, it is not always practical
  - Only useful if you can test a counter against zero
  - Doesn't work when you want to count up
    - For tests with a fixed start value against a fixed end value, the compiler may be able to compute the count and use the `loop` instruction

```
for (i = 0; i < 10; i++) {
```

    - But only if i is not used in the loop body

# Loops (cont)

- In high level languages most loops appear to test at the top
  - Conditional jump exits loop when test fails or falls through to continue loop
- End of loop body requires unconditional jump back to top
- Most compilers rearrange loops to contain only a single conditional jump
  - Unconditional jump factored out

# While Loop

- Test condition
- Jump if false to first statement following loop body
- Last statement in loop body jumps back to test

# While (naïve example)

```
top:
     cmp eax, ebx     ;while
     jge end_loop     ; (eax < ebx) {

     ;loop body

     jmp top          ;}
end_loop:
```

# While (common example)

```
    cmp eax, ebx  ;pretest allows
    jge end_loop  ;case of 0 passes
top:              ;do {
    ;loop body
    cmp eax, ebx    ;} while
    jl top          ; (eax < ebx);
end_loop:
```

# Example

- Navigate back to main
- The function called after if _else is named while_loop (sub_4011D1)
- Navigate to the while_loop function
- Note the use of heavier lines for backward jumps
  - This is how ida tries to point out a potential loop

# Loop Caution

- Don’t assume that a register will contain your loop variable for the duration of a loop
- In a long loop body, the registers involved in the original test may be reused for other purposes.
- Registers need to get reloaded prior to performing loop continuation test

# For Loops

- Loop initialization performed immediately prior to the top of the loop
- Counting statements placed at the end of the loop body immediately prior to the jump back to the top
- Test usually takes place at the bottom of the loop

# For (example)

```
    xor ebx, ebx        ;for (j = 0;
top:
    cmp ebx, 10         ;
    jge end_loop        ; j < 10;
    ;loop body
    inc  ebx            ; j++)
    jmp top             ;}
end_loop:
```

# Alternative For (example)

```
    xor ebx, ebx        ;for (j = 0;
    jmp test
top:
    ;loop body
    inc  ebx            ; j++)
test:
    cmp ebx, 10         ;
    jl top              ; j < 10;
end_loop:
```

# Examples

- The next two functions called from main contain for loops
- The functions are named for_loop and for_loop_down respectively
- In each you can see loop initialization, the testing, and the increment phases

# Ida and Strings

- Strings can be very useful in determining the behavior of a binary
  - If nothing else they reveal the use of a char* data type
- When Ida recognizes strings in the data section of a binary, it groups all characters of the string together into a static string variable

# Ida String Example

- The function for_loop_down (sub_4011FE) references a string variable
- Note what Ida has done with the string
  - Automatically names the string variable
    - aZZZZZ where ZZZZ are the characters in the string
  - Adds a comment that shows the content of the string


.text:004011FE for_loop_down proc near ; CODE XREF: _main+58↓p
.text:004011FE push ebp
.text:004011FF mov ebp, esp
.text:00401201 xor ecx, ecx
.text:00401203 mov edx, offset aHelloWorld ; "Hello World!"
.text:00401208 mov eax, 0Bh
.text:0040120D
.text:0040120D loc_40120D: ; CODE XREF: for_loop_down+19↓j
.text:0040120D cmp byte ptr [edx+eax], 6Ch
.text:00401211 jnz short loc_401214
.text:00401213 inc ecx
.text:00401214
.text:00401214 loc_401214: ; CODE XREF: for_loop_down+13↑j
.text:00401214 dec eax
.text:00401215 test eax, eax
.text:00401217 jge short loc_40120D
.text:00401219 mov eax, ecx
.text:0040121B pop ebp
.text:0040121C retn
.text:0040121C for_loop_down endp
.text:0040121C
heavy line for backward jumps
default string variable name
data cross reference
.data:00409126 db 0
.data:00409127 db 0
.data:00409128 aHelloWorld db 'Hello World!',0 ; DATA XREF: for_loop_down+5↑o
.data:00409135 align 4
.data:00409138 dword_409138 dd 0 ; DATA XREF: @_virt_reserve+7↑r
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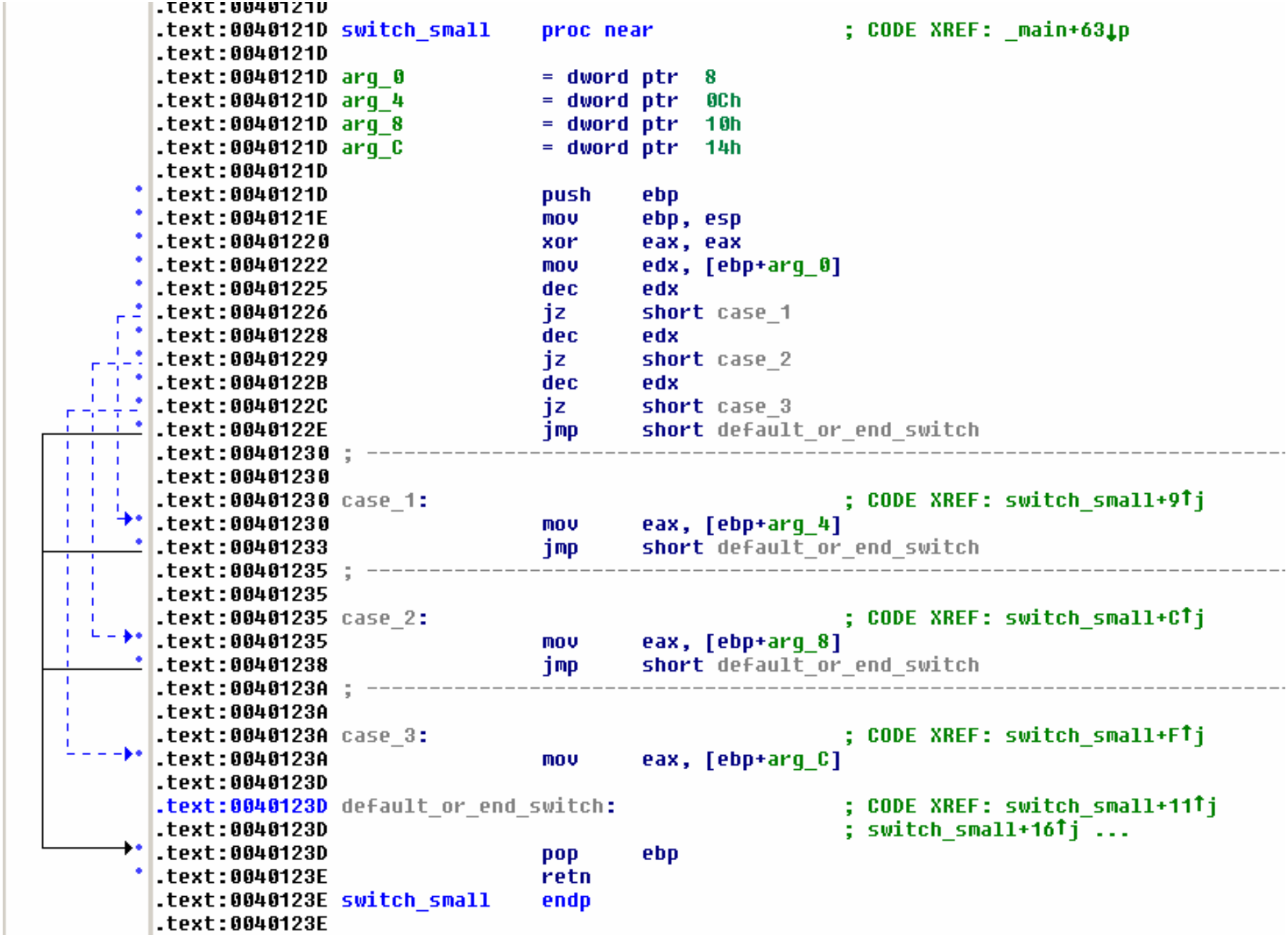
# Switch Statements

- Can be done in many ways
- The slowest way
  - A sequence of tests against each case
    - break statements translate to jumps to first statement after switch
  - If no match found must result in default case or end of switch
- The fastest way
  - Vectored jump based on the switch variable
  - Wastes space if cases are not entirely sequential

# Example

- Navigate back to main
- sub_40121D corresponds to switch_small
- Navigate to switch_small
  - Small number of consecutive cases
  - Successive decrement and test
- Take a look at the flowchart
  - Doesn't necessarily suggest a switch



# Larger Switches

- Consecutive case handled with jump tables
- Non-consecutive cases handled with subtract and test
  - Subtract smallest constant test for zero
  - Subtract delta to next smallest, test for zero
  - Repeat

# Jump Table

- Assume eax holds switch variable which ranges from 0..N

```
mov     ebx, jump_table   ;address of table
jmp     [ebx + eax * 4]
```

- jump_table is the address of the first entry (item 0) in a list of addresses for each case
  - Each address occupies 4 bytes, hence eax * 4

# Jump Tables (cont)

- Jump tables can be used for any consecutive range of values, simply normalize to zero
- In this example, the cases run from 32..64

```
mov     ebx, jump_table;address of table
sub     eax, 32
jmp     [ebx + eax * 4]
```

# Example

- Navigate to function switch_large (sub_41023F)
- In this case, Ida recognizes the jump tables and labels things accordingly
  - This is Borland code which Ida knows well
- Ida does not always do so well
  - You need to recognize it on your own in those cases

```
.text:0040123E                  retn
.text:0040123E switch_small     endp
.text:0040123E
.text:0040123F
.text:0040123F ; ||||||||||||||| S U B R O U T I N E |||||||||||||||||||||||||||||||||||||||
.text:0040123F
.text:0040123F ; Attributes: bp-based frame
.text:0040123F
.text:0040123F switch_large     proc near               ; CODE XREF: _main+71↓p
.text:0040123F
.text:0040123F arg_0            = dword ptr  8
.text:0040123F arg_4            = dword ptr  0Ch
.text:0040123F arg_8            = dword ptr  10h
.text:0040123F arg_C            = dword ptr  14h
.text:0040123F
.text:0040123F                  push    ebp
.text:00401240                  mov     ebp, esp
.text:00401242                  xor     eax, eax
.text:00401244                  mov     edx, [ebp+arg_0]
.text:00401247                  cmp     edx, 0Ch        ; switch 13 cases
.text:0040124A                  ja      loc_4012E0      ; default
.text:00401250                  jmp     ds:off_401257[edx*4] ; switch jump
.text:00401250 ; ---------------------------------------------------------------------------
.text:00401257 off_401257       dd offset loc_4012E0    ; DATA XREF: switch_large+11↑r
.text:00401257                  dd offset loc_40128B    ; jump table for switch statement
.text:00401257                  dd offset loc_401290
.text:00401257                  dd offset loc_401295
.text:00401257                  dd offset loc_40129A
.text:00401257                  dd offset loc_4012A2
.text:00401257                  dd offset loc_4012AA
.text:00401257                  dd offset loc_4012B2
.text:00401257                  dd offset loc_4012BA
.text:00401257                  dd offset loc_4012C2
.text:00401257                  dd offset loc_4012CA
.text:00401257                  dd offset loc_4012D2
.text:00401257                  dd offset loc_4012DA
.text:0040128B ; ---------------------------------------------------------------------------
.text:0040128B
.text:0040128B loc_40128B:                              ; CODE XREF: switch_large+11↑j
.text:0040128B                                          ; DATA XREF: switch_large:off_401257↑o
.text:0040128B                  mov     eax, [ebp+arg_4] ; case 0x1
.text:0040128E                  jmp     short loc_4012E0 ; default
.text:00401290 ; ---------------------------------------------------------------------------
```

**switch variable test**

**Ida recognizes case 1**

# Switch Weirdness

- Apparent optimization for non-linear cases
  - Successive subtraction
    - Subtract smallest case value
      - If zero, then it's a match
      - If non-zero, then subtract delta to next smallest and so on
    - If any cases are consecutive, then simply use dec rather than sub

# Example

- Navigate to function switch_gaps (sub_4102E2)
- In this case, Ida recognizes the consecutive cases and uses a jump table
- Non-consecutive tables handle using subtraction

```
.text:004012E5                  xor     eax, eax
.text:004012E7                  mov     edx, [ebp+arg_0]
.text:004012EA                  cmp     edx, 9
.text:004012ED                  jg      short loc_401329
.text:004012EF                  jz      loc_40139D
.text:004012F5                  cmp     edx, 8          ; switch 9 cases
.text:004012F8                  ja      loc_4013DB      ; default
.text:004012FE                  jmp     ds:off_401305[edx*4] ; switch jump
.text:004012FE ; ---------------------------------------------------------------------------
.text:00401305 off_401305       dd offset loc_4013DB    ; DATA XREF: switch_gaps+1C↑r
.text:00401305                  dd offset loc_401366    ; jump table for switch statement
.text:00401305                  dd offset loc_40136B
.text:00401305                  dd offset loc_401370
.text:00401305                  dd offset loc_401375
.text:00401305                  dd offset loc_40137D
.text:00401305                  dd offset loc_401385
.text:00401305                  dd offset loc_40138D
.text:00401305                  dd offset loc_401395
.text:00401329 ; ---------------------------------------------------------------------------
.text:00401329
.text:00401329 loc_401329:                              ; CODE XREF: switch_gaps+B↑j
.text:00401329                  cmp     edx, 205
.text:0040132F                  jg      short loc_40134C
.text:00401331                  jz      loc_4013BD
.text:00401337                  sub     edx, 10
.text:0040133A                  jz      short loc_4013A5
.text:0040133C                  sub     edx, 193
.text:00401342                  jz      short loc_4013AD
.text:00401344                  dec     edx
.text:00401345                  jz      short loc_4013B5
.text:00401347                  jmp     loc_4013DB      ; default
.text:0040134C ; ---------------------------------------------------------------------------
.text:0040134C
.text:0040134C loc_40134C:                              ; CODE XREF: switch_gaps+4D↑j
.text:0040134C                  sub     edx, 206
.text:00401352                  jz      short loc_4013C5
.text:00401354                  sub     edx, 846
.text:0040135A                  jz      short loc_4013CD
.text:0040135C                  sub     edx, 1037
.text:00401362                  jz      short loc_4013D5
.text:00401364                  jmp     short loc_4013DB ; default
.text:00401366 ; ---------------------------------------------------------------------------
```

# Reversing Function Calls

- call statement easily recognized in disassembly
- Usually preceded by a series of push operations to get parameters on the stack
  - Sometimes "mov" is used rather than push
    - In this case, space must have been pre-allocated for the parameters
    - Compare with asm_code_samples_gcc.exe

# Pushing Parameters - Example

```
fprintf(stdout, "This program has %d …", arg_0);

.text:0804848D   push    [ebp+arg_0]
.text:08048490   push    offset aThisProgramHas
      ; "This program has %d command line argume"...
.text:08048495   push    ds:stdout
.text:0804849B   call    _fprintf
```

# Push via mov Example

```
sub_804844C(getenv("HELLOWORLD"));


.text:080484AE   mov   [esp+8+var_8], offset aHelloworld
                                          ; "HELLOWORLD"
.text:080484B5   call  _getenv
.text:080484BA   mov   [esp+8+var_8], eax
.text:080484BD   call  sub_804844C
```

# Linux System Calls

- Invoked using an `int 0x80`
  - This is a software interrupt
  - Transfers control to the kernel
    - Transitions to kernel stack so we can't pass our parameters on the user stack
      - We could but would need to perform a user to kernel space copy operation
  - Parameters passed in various CPU registers

# Linux System Calls (ii)

- There are about 190 different system calls
  - But there is only one `int 0x80`
- Specify which system call you wish to make by placing the syscall number into eax before executing `int 0x80`
- Not well documented
  - http://www.linuxassembly.org/syscall.html

# Linux System Calls (iii)

- Like a function call, each system call expects zero or more parameters
- System calls expect their parameters in very specific registers

# Linux System Calls (iv)

- Syscall parameters (if necessary)
  - `ebx` – first parameter
  - `ecx` – second parameter
  - `edx` – third parameter
  - `esi` – fourth parameter
  - `edi` – fifth parameter

# Useful System Calls

| Name | Number | ebx | ecx | edx |
|---|---|---|---|---|
| sys_exit | 1 | int retval | | |
| sys_read | 3 | int fd | char *buf | size_t len |
| sys_write | 4 | int fd | char *buf | size_t len |
| sys_open | 5 | char *name | int flags | int mode |
| sys_close | 6 | int fd | | |
| sys_execve | 11 | char *file | char **argv | char **envp |
| sys_socketcall | 102 | int call | ulong *args | |

# Syscalls and Reverse Engineering

- You will usually only see systems calls in two types of code
  - Shellcode
    - Allow for smallest possible shellcode with no need to link to compiled libraries
  - Statically linked code
    - All library functions linked in with user code to form stand alone executable
    - Makes code independent of installed libraries

# Ida Pro

- When analyzing Linux binaries, Ida recognizes the int 0x80 instruction and attempts to comment the preceding instructions based on current value in eax
- Not always possible for Ida to know eax value

# Additional Ida Features

# Reverse Engineering Goals

- Discover how a program works
  - Build compatible software
- Locate hidden functionality
  - Backdoors etc.
- Search for vulnerabilities in closed source software
- All start with a quality disassembly
  - We will assume Ida is used for this class

# Analysis

- Trace code to understand how it works
  - Could generate your own high level code as you go
- Observe/Understand function call tree
- Understand data types
  - Everything looks the same in assembly
    - Is a 4 byte quantity an int, float, or pointer?
    - Depends on how it is used

# Analyzing Functions

- Two approaches
  - Breadth first
    - Understand a function, then try to understand the functions that are called
  - Depth first
    - Descend into each function as it is called
      - At some point you will get to a function that calls no others or invokes only system/api calls
      - If the former, attempt to figure out what the function does
      - If the later make note of the data passed to the system calls and bubble the types back out toward your initial function

# Analyzing Data

- Determining data types used in a program helps determine its functionality
- One of the best ways to determine data types is to look for calls to known functions
  - C standard library calls
  - O/S API calls
- Observe the parameters passed to these functions and name them accordingly

# Automated Analysis

- The quality of your disassembler makes a big difference
- IdaPro contains signatures for most of the standard library calls made in C programs
- When Ida sees a call to a known function it annotates your code with known variable type and parameter name information

# Ida Pro Strengths

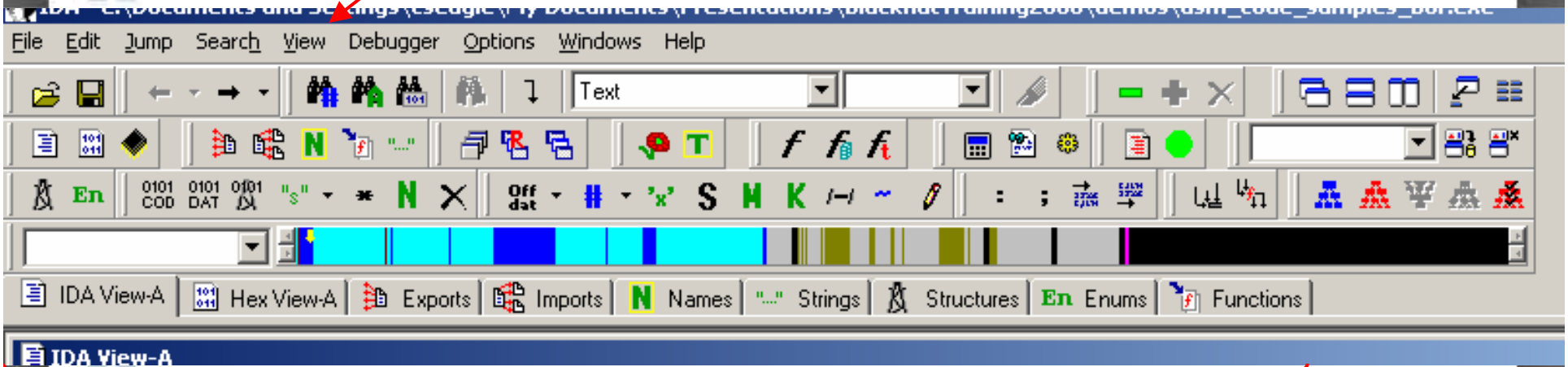
- GUI provides easy navigation and multiple windows of useful info
  - Graphical display of control flow
  - Double click navigation
- Understands many library calls and data types
  - Particularly strong against Windows binaries
- Allows you to annotate your disassemblies

# Various Other Windows

- Hex view
  - Raw hex display, tracks along with IDA View
- Segments
  - Breakdown of program segments and virtual addresses assigned to each
- All accessible via View/Open subviews menu item

# Ida Subwindows

**Open/reopen other windows from the View menu**




**Windows opened at startup**

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# Revisiting Ida Stack Displays

- Ida only assigns names to locations that are actually referenced in a function
- s and r are Ida standard names for the saved register space and saved return address respectively
- Accounts for every byte on stack
- Data sizes
  - db = byte
  - dw = word = 2 bytes
  - dd = double word = 4 bytes

# Stack Based Arrays

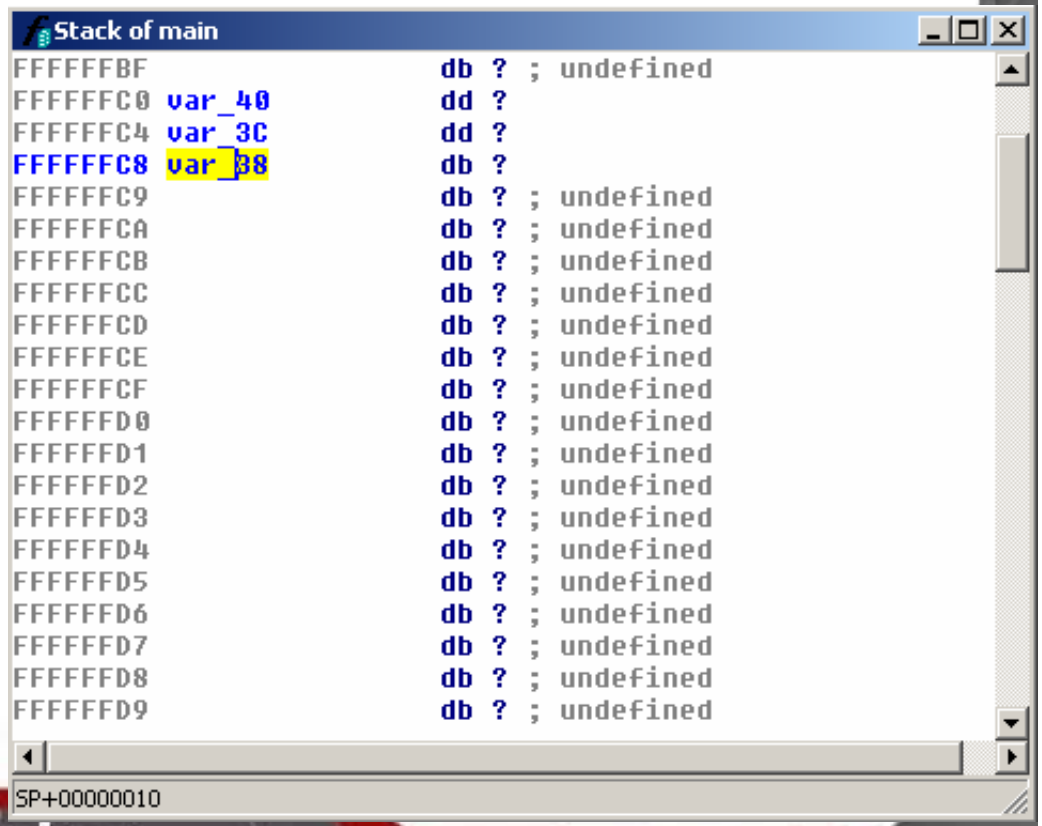
- Open demos/proj4 binary
  - Probably need to set file type filter to*.*
  - Note that Ida properly identifies it as an ELF binary
- Code for main begins:

```
int main(int argc, char **argv, char **envp) {
   unsigned int index;
   char buf[32];
```

  - 36 bytes of stack locals

# Example

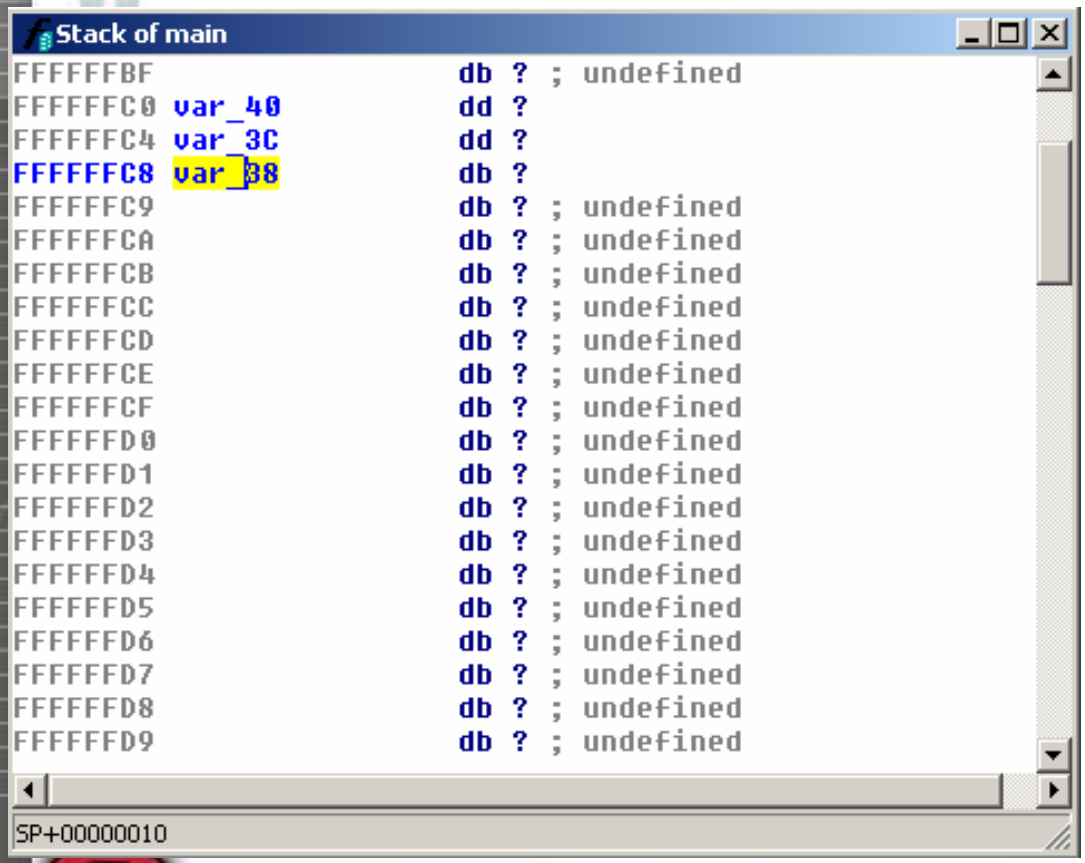
- Double click on var_38 to bring up the stack frame view

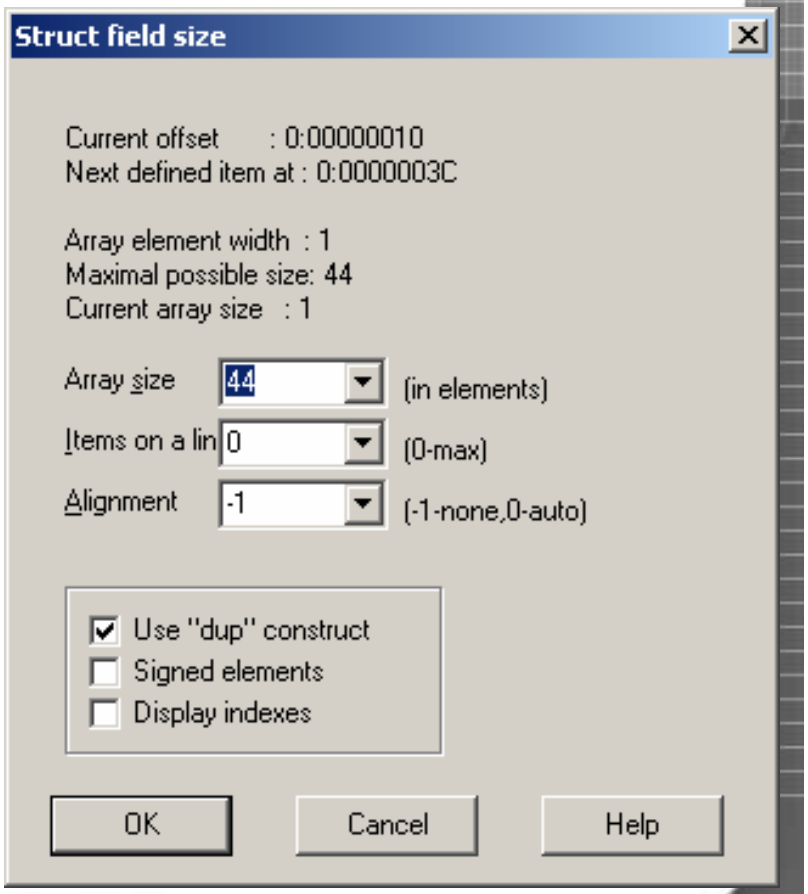


# Stack Frame View

- Stack based arrays consume a lot of space in the view
  - Ida often identifies start as dd
  - Many unnamed db lines – why?
- Ida allows you to group consecutive memory locations into arrays
  - Find the start of the array
  - Set the data size (d key toggles between db, dw, dd)
  - Select (Num *) key or click the * tool button to create an array
  - Ida guesses at a proper size

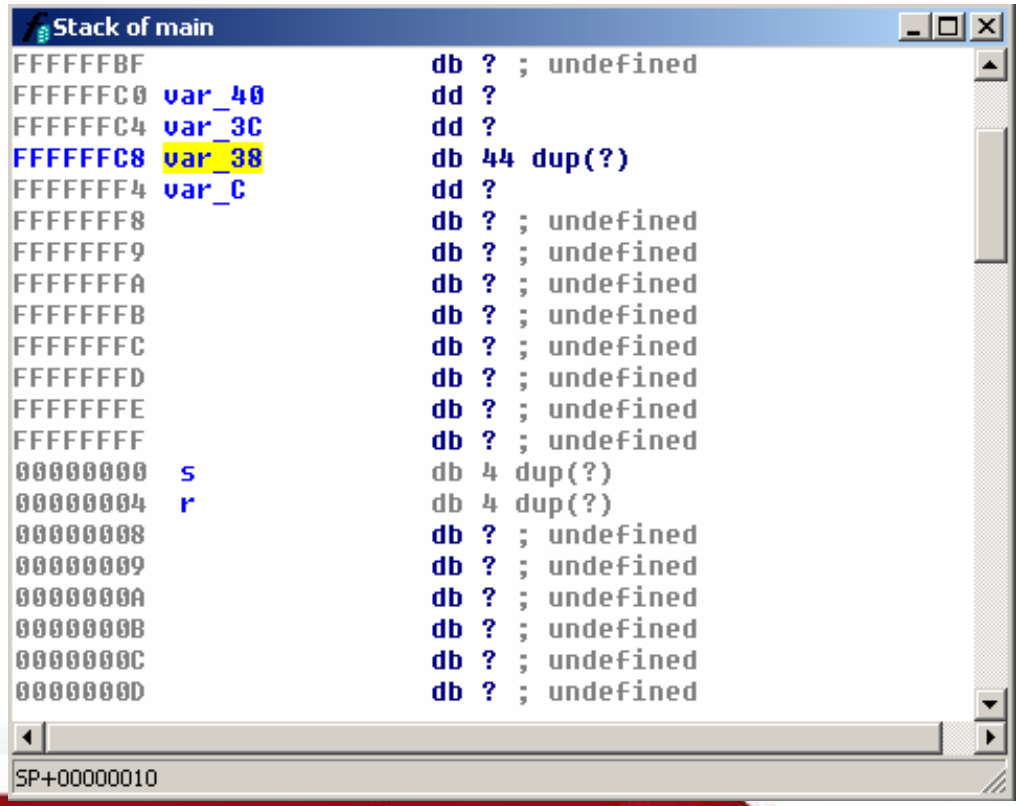
# Creating an Array



# Creating an Array

- Ida collapses the array variable and all accompanying bytes into a single statement



# Collapsing Arrays

- Two notes
  - Compilers often insert padding bytes after arrays
    - Hence the 44 byte array rather than the 32 bytes we asked for
  - The disassembly shows us the exact number of bytes that would be required to overflow the buffer and corrupt other data

# Control Flow

- In the left margin, Ida indicates control flow for jumps with arrows/lines showing the direction and target of jumps
  - Conditional jumps – dashed
  - Unconditional jumps – solid
  - Backward jumps – heavier line
- Very useful in identifying branching and looping constructs

# Sample (proj3a)

- In this case a loop is shown as flow is backwards

```
.text:080484A3                 mov     [ebp+var_4], 0
.text:080484AA
.text:080484AA loc_80484AA:                            ; CODE XREF: main+77↓j
.text:080484AA                 mov     eax, [ebp+var_4]
.text:080484AD                 cmp     eax, [ebp+arg_0]
.text:080484B0                 jl      short loc_80484B4
.text:080484B2                 jmp     short loc_80484DE
.text:080484B4 ; ---------------------------------------------------------------------------
.text:080484B4
.text:080484B4 loc_80484B4:                            ; CODE XREF: main+4B↑j
.text:080484B4                 sub     esp, 4
.text:080484B7                 mov     eax, [ebp+var_4]
.text:080484BA                 lea     edx, ds:0[eax*4]
.text:080484C1                 mov     eax, [ebp+arg_4]
.text:080484C4                 push    dword ptr [eax+edx]
.text:080484C7                 push    [ebp+var_4]
.text:080484CA                 push    offset aArgvDS  ; "argv[%d]: %s\n"
.text:080484CF                 call    _printf
.text:080484D4                 add     esp, 10h
.text:080484D7                 lea     eax, [ebp+var_4]
.text:080484DA                 inc     dword ptr [eax]
.text:080484DC                 jmp     short loc_80484AA
.text:080484DE ; ---------------------------------------------------------------------------
.text:080484DE
.text:080484DE loc_80484DE:                            ; CODE XREF: main+4D↑j
.text:080484DE                 sub     esp, 0Ch
```

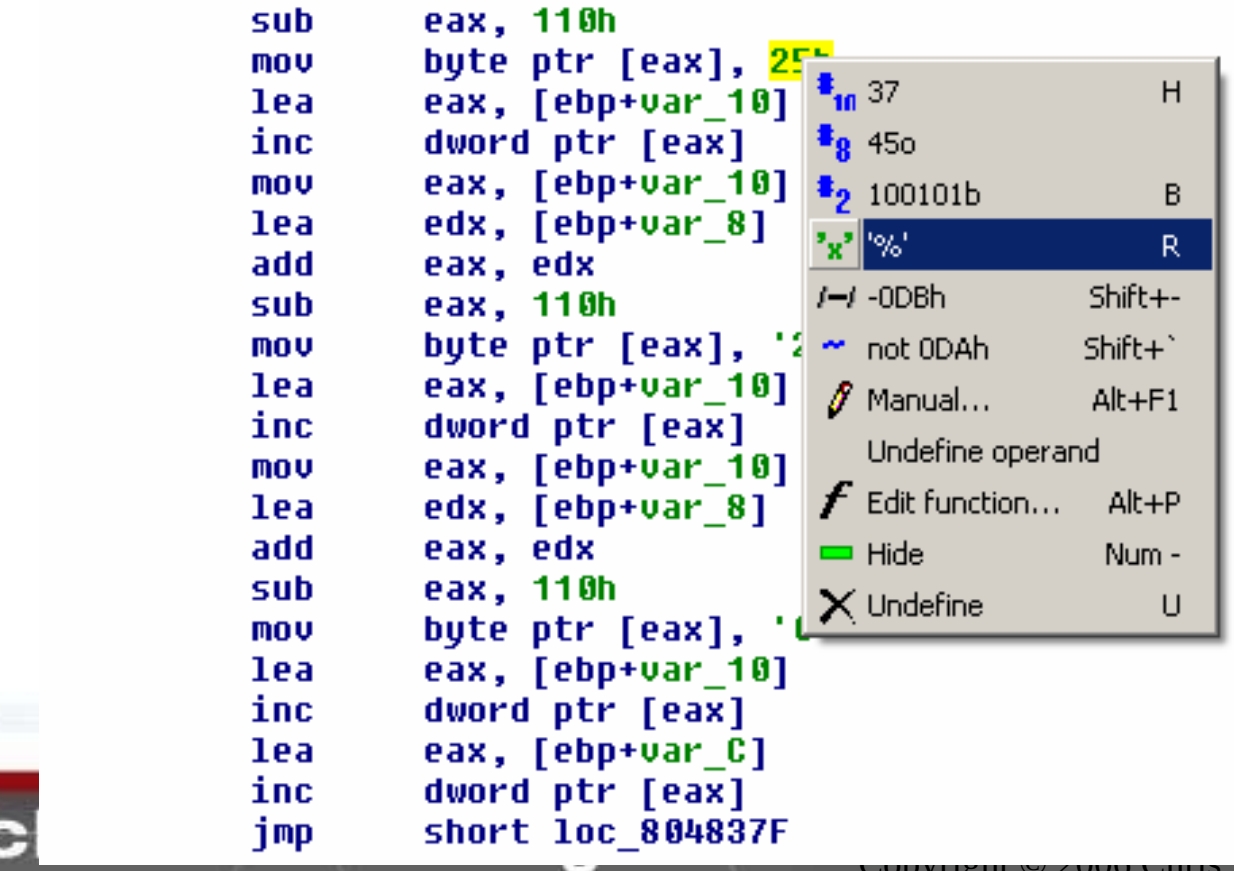
# Data Display

- Ida allows selection of alternate data displays
  - Hex, octal, decimal, binary, ASCII

```
lea     edx, [ebp+var_8]
add     eax, edx
sub     eax, 110h
mov     byte ptr [eax], 25h
lea     eax, [ebp+var_10]
inc     dword ptr [eax]
mov     eax, [ebp+var_10]
lea     edx, [ebp+var_8]
add     eax, edx
sub     eax, 110h
mov     byte ptr [eax], '2'
lea     eax, [ebp+var_10]
inc     dword ptr [eax]
mov     eax, [ebp+var_10]
lea     edx, [ebp+var_8]
add     eax, edx
sub     eax, 110h
```

# Changing Data Format

- Right click on data item or choose Edit/Operand Type



# Ida Cross Referencing

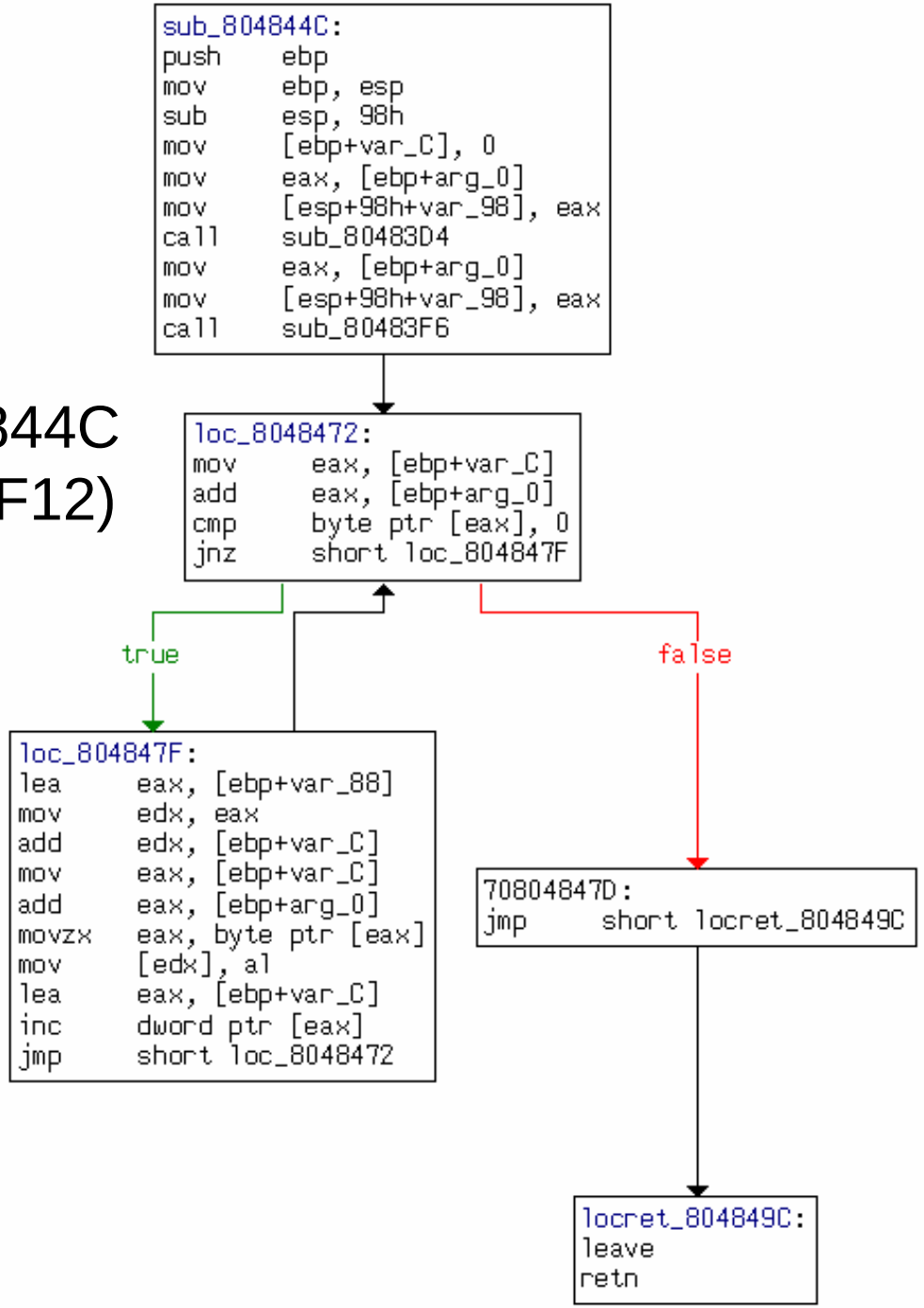
- On initial analysis, Ida creates cross references every chance it gets
- Cross references are displayed as comments in the right margin of the disassembly
- Cross references indicate what other lines of code refer to the current line
  - Very useful for understanding control flow

# Ida Graphing

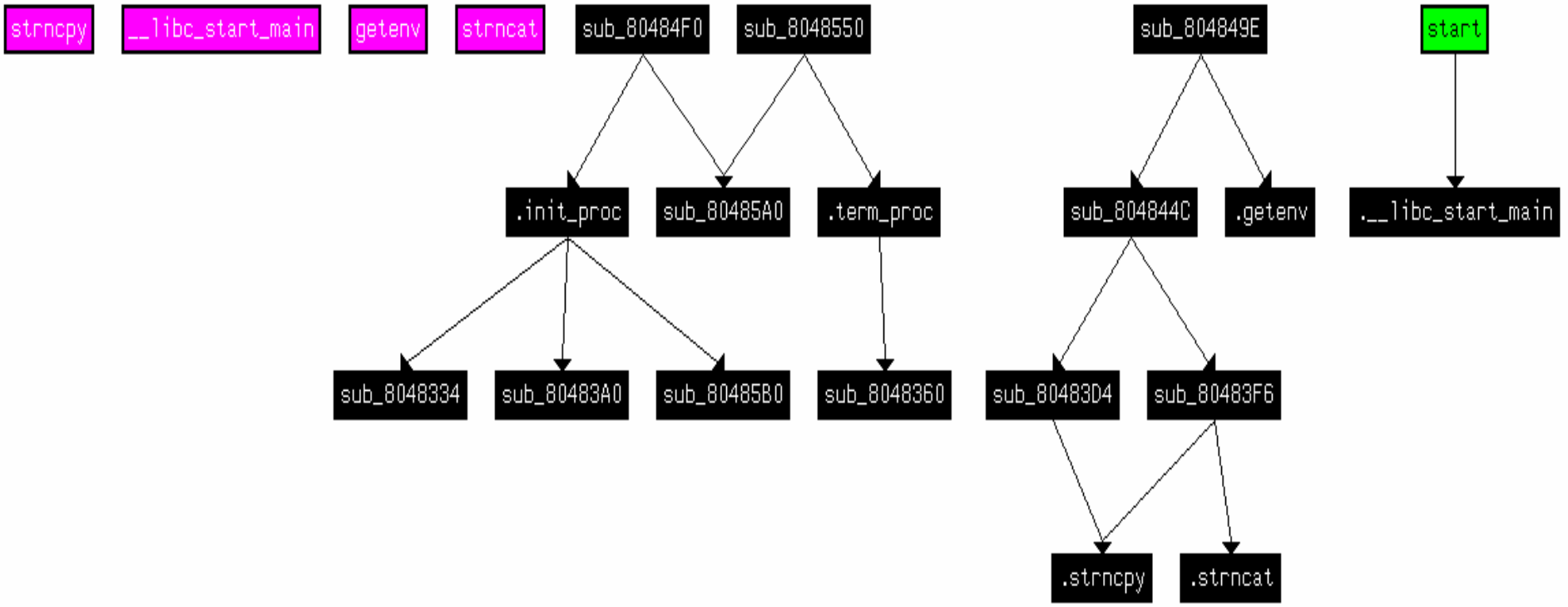
- Cross references form the foundation for a very useful feature of Ida Pro, graphing
- The following graphs can be generated
  - Function flow charts
  - The entire function call tree (forest) for a program
  - All xrefs from a function
    - Who do I call?
  - All xrefs to a function
    - Who calls me?

# Flow Chart

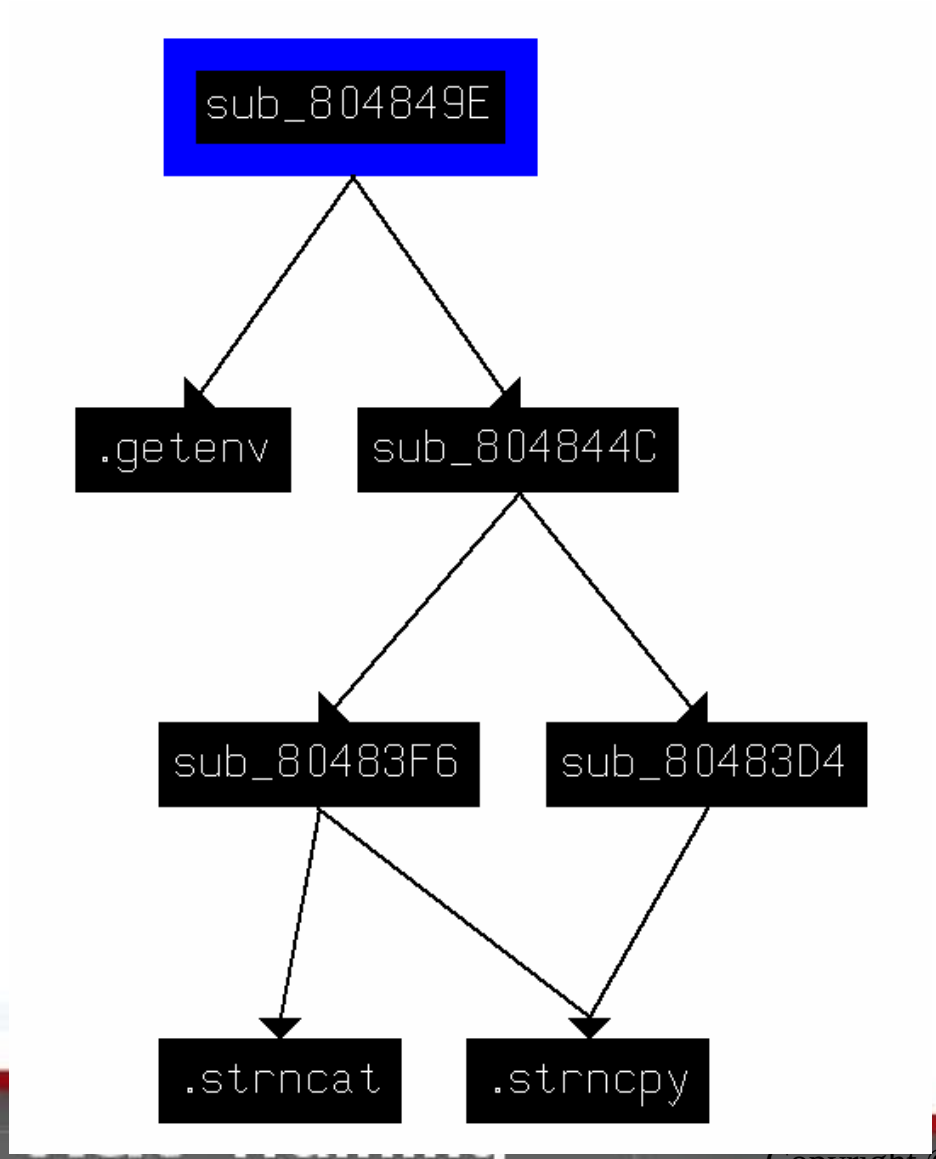
- demos/stage4, sub_804844C
- View/Graphs/Flowchart (F12)



# Function Call Graph (stage4)



# Xrefs From (stage4, sub_804849E)



# Graphing Limitations

- Graphs are not interactive
  - Not navigable, collapsible or editable
  - Lose address information
  - Can’t prune
- Often too much information to be useful
- Graphing utility is stand alone app
- No access to generated graph source code or graphing functionality via api

# Graphing Improvements

- Third party developers have filled a need
  - Sabre's BinDiff, BinNavi
  - Pedram Amini's ProcessStalker
- Ida 5.0 will introduce many new features
  - Integrating graphing
  - Graphing api directly accessible to plugin developers

# Ida Comments

- There are several types of comments you can add to a disassembly
  - Access via Edit/Comments menu or hotkeys
  - We have already seen standard comments
- Three additional types
  - Anterior lines
    - Entire preceding line dedicated to comment text
  - Posterior lines
    - Entire succeeding line dedicated to comment text
  - Repeatable comments

# Repeatable Comments

- Repeatable comments are repeated at any location that refers to the original commented location
- Entered with ; hotkey
- Useful, for example, when you have commented a data item and you wish to see that comment where the data item is referenced

# Commented Code

- Note that Ida uses comments itself to display things like references and function header info

```
.text:00000A60 while_loop:                             ; CODE XREF: apcon_filter_in+1F9↓j
.text:00000A60                 mov     eax, [ebp+str]
.text:00000A66                 movzx   eax, byte ptr [ecx+eax]
.text:00000A6A                 cmp     al, ' '
.text:00000A6C                 jz      expand_space
.text:00000A72                 cmp     al, '\'
.text:00000A74                 jz      do_slash
.text:00000A7A                 mov     [ebp+edx+data], al ; THIS IS VULNERABLE!!
.text:00000A81                 inc     ecx
.text:00000A82                 inc     edx
.text:00000A83
.text:00000A83 while_test:                             ; CODE XREF: apcon_filter_in+27B↓j
.text:00000A83                 cmp     ecx, [ebp+length]
.text:00000A89                 jl      short while_loop
.text:00000A8B
```

# Data Types and Data Structures

Black Hat Training

# Ida Structures

- User defined/complex data type are used frequently in programming
  - C struct for example
- Tough to disassemble because field access is a complex operation in assembly
- Ida allows you to define struct data types and refer to the offsets in your disassembly

# Example

- Open demos/fetch
- The call to connect requires a sockaddr_in, so var_28 must be one

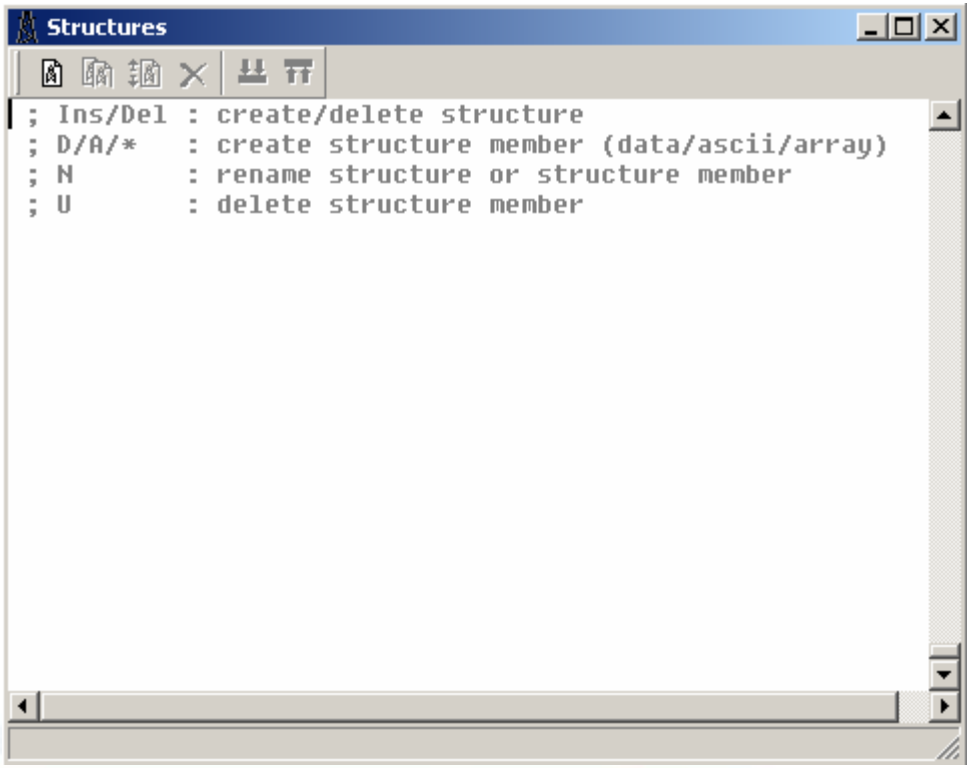
```
.text:080484FE                push    eax             ; struct in_addr *
.text:080484FF                push    offset a205_155_71_181 ; "205.155.71.181"
.text:08048504                call    _inet_aton
.text:08048509                add     esp, 10h
.text:0804850C                sub     esp, 4
.text:0804850F                push    0               ; protocol
.text:08048511                push    1               ; type
.text:08048513                push    2               ; family
.text:08048515                call    _socket
.text:0804851A                add     esp, 10h
.text:0804851D                mov     [ebp+var_C], eax
.text:08048520                sub     esp, 4
.text:08048523                push    10h             ; int
.text:08048525                lea     eax, [ebp+var_28]
.text:08048528                push    eax             ; struct sockaddr *
.text:08048529                push    [ebp+var_C]     ; int
.text:0804852C                call    _connect
.text:08048531                add     esp, 10h
.text:08048534                push    0               ; flags
```

# Sidenotes

- Ida 4.9 does a better job of automatically applying type information to disassemblies than previous versions
- The snippet on the previous slide was generated with 4.9
- The same binary loaded in 4.8 will show no type info at all

# Structures Window

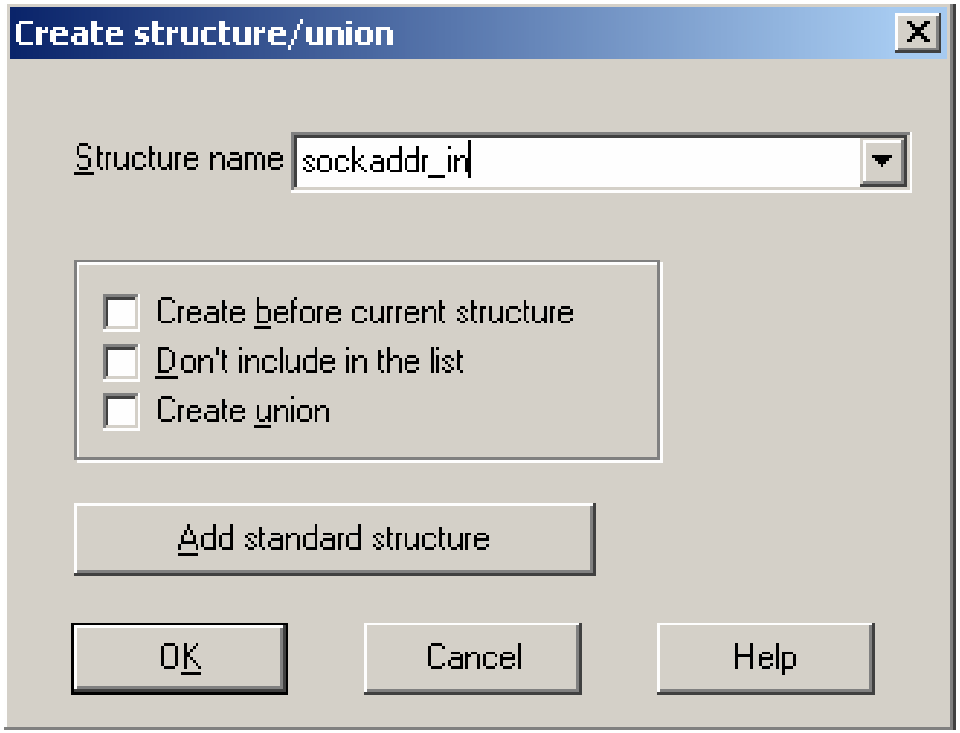
- Bring up from View/Open Subviews/Structures
- This is where you create and edit structures



# Creating a new struct

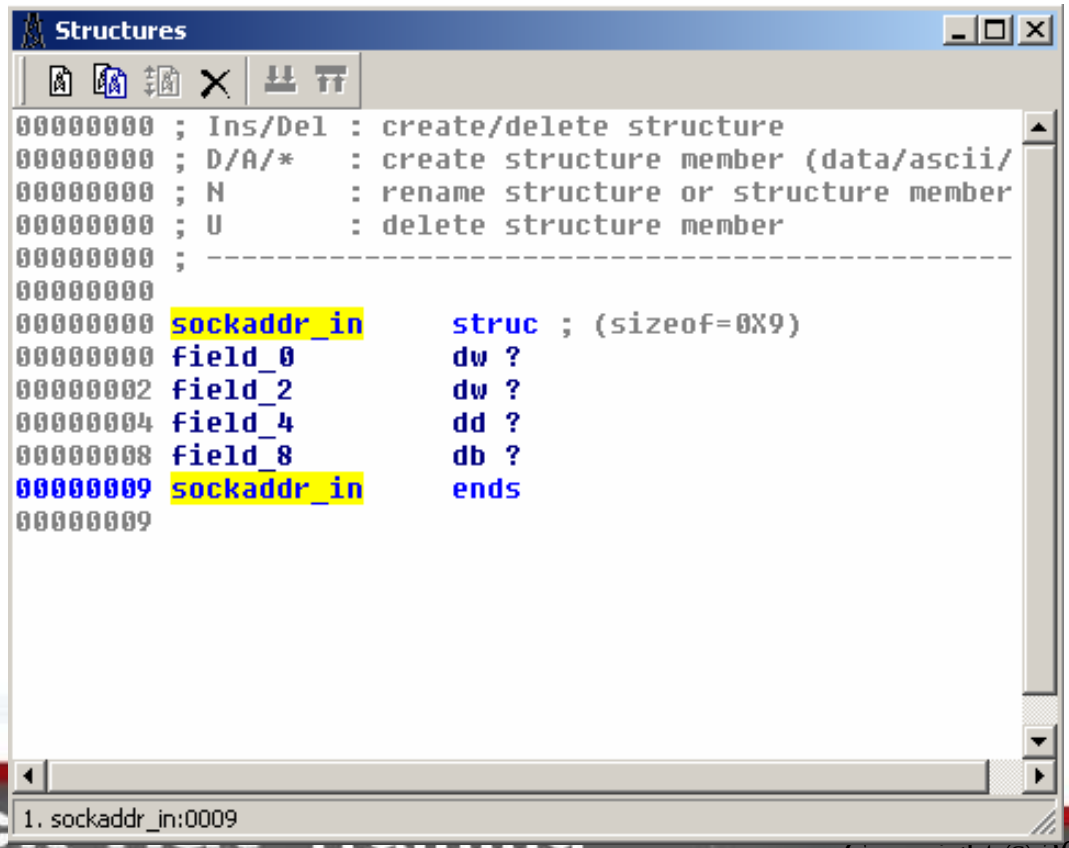
- Press the Insert key
- Give the structure a name
  - Or add a standard struct
  - For Windows binaries, Ida has a large number of predefined standard structs
  - For Linux/Unix you may need to add a type library
- Add new fields using the d key
- Name the fields using the n key

# New Struct



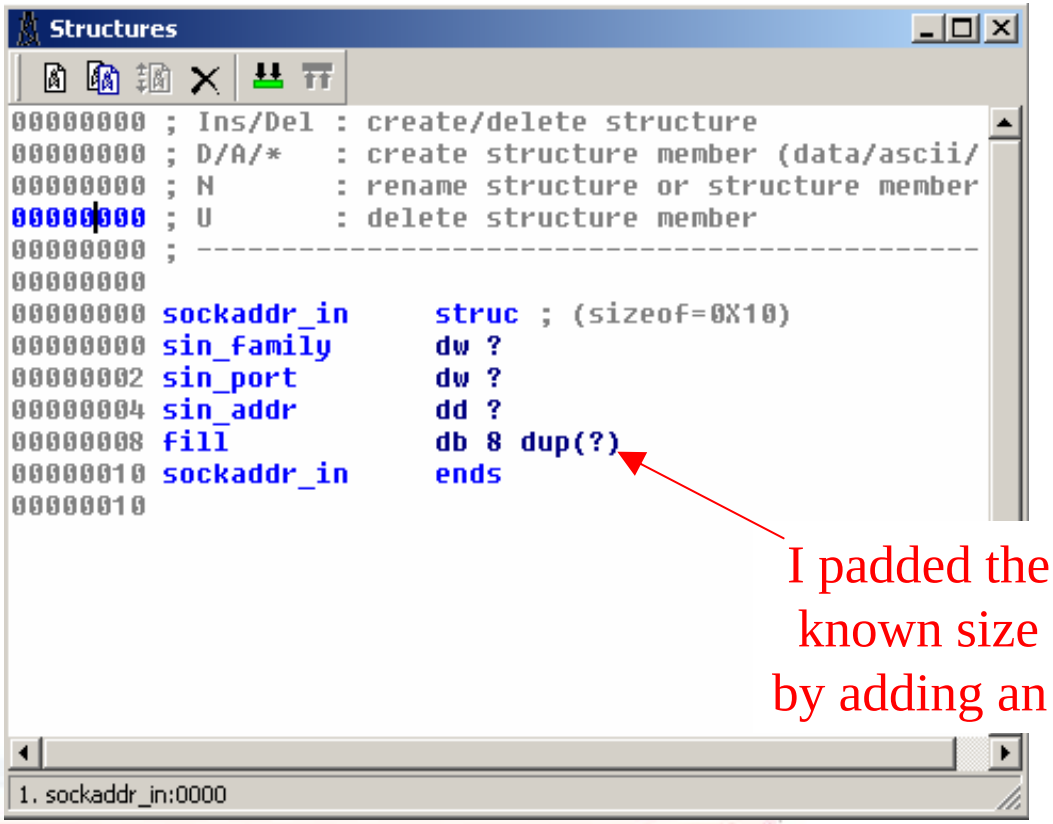
# Adding Fields

- Add fields based on what you see or what you know (if you have the source)



# Naming Fields

- Name the fields (n key)

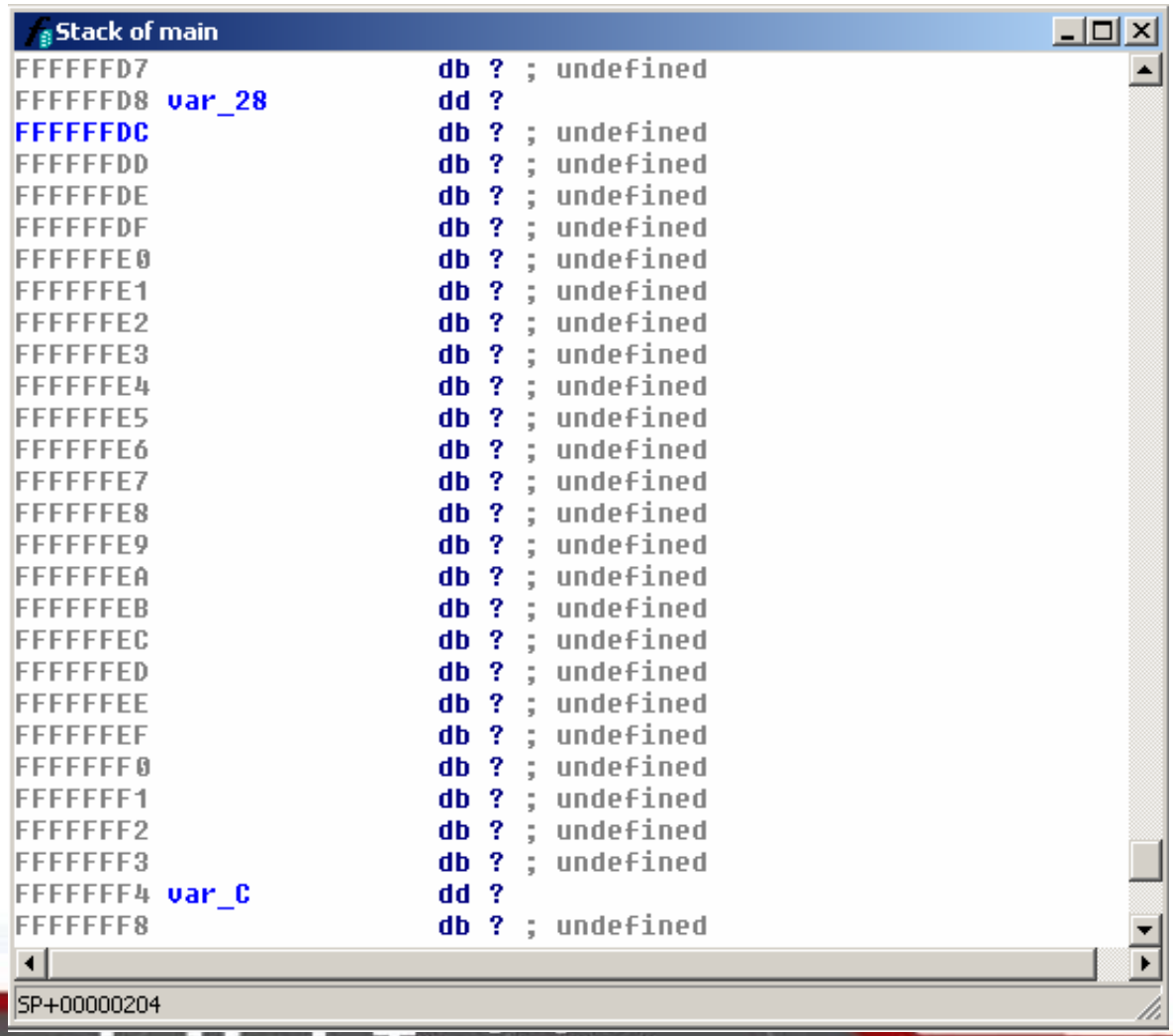



I padded the struct to its known size of 16 bytes by adding an 8 byte array

# Applying Struct Templates

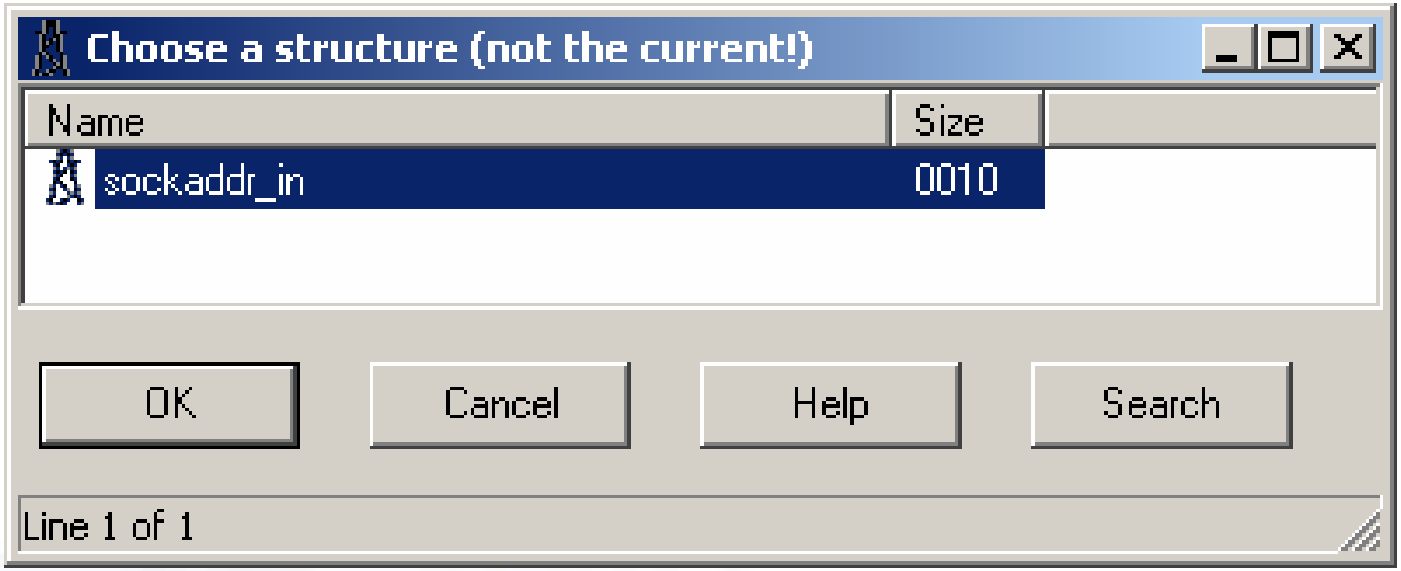
- In your disassembly, click on the variable that is to become a struct
  - If it is a stack variable, you should be in stack view
- Select the Edit/Struct var…menu option
- Double click on the name of the desired structure

# Select Struct Variable

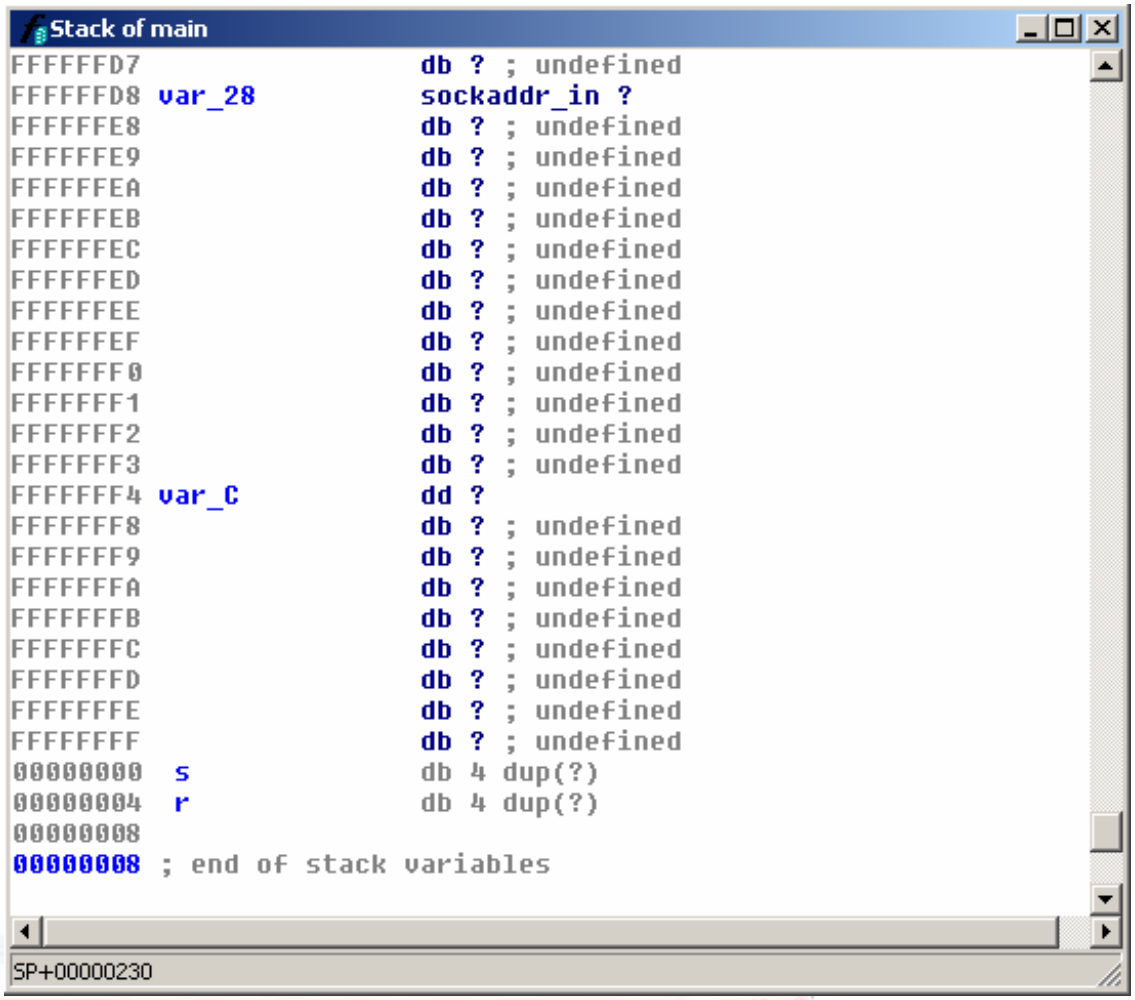


# Select Struct

- Note: Ida 4.9 users should redesignate var_28 as a sockaddr_in



# Result



# Using Struct Fields

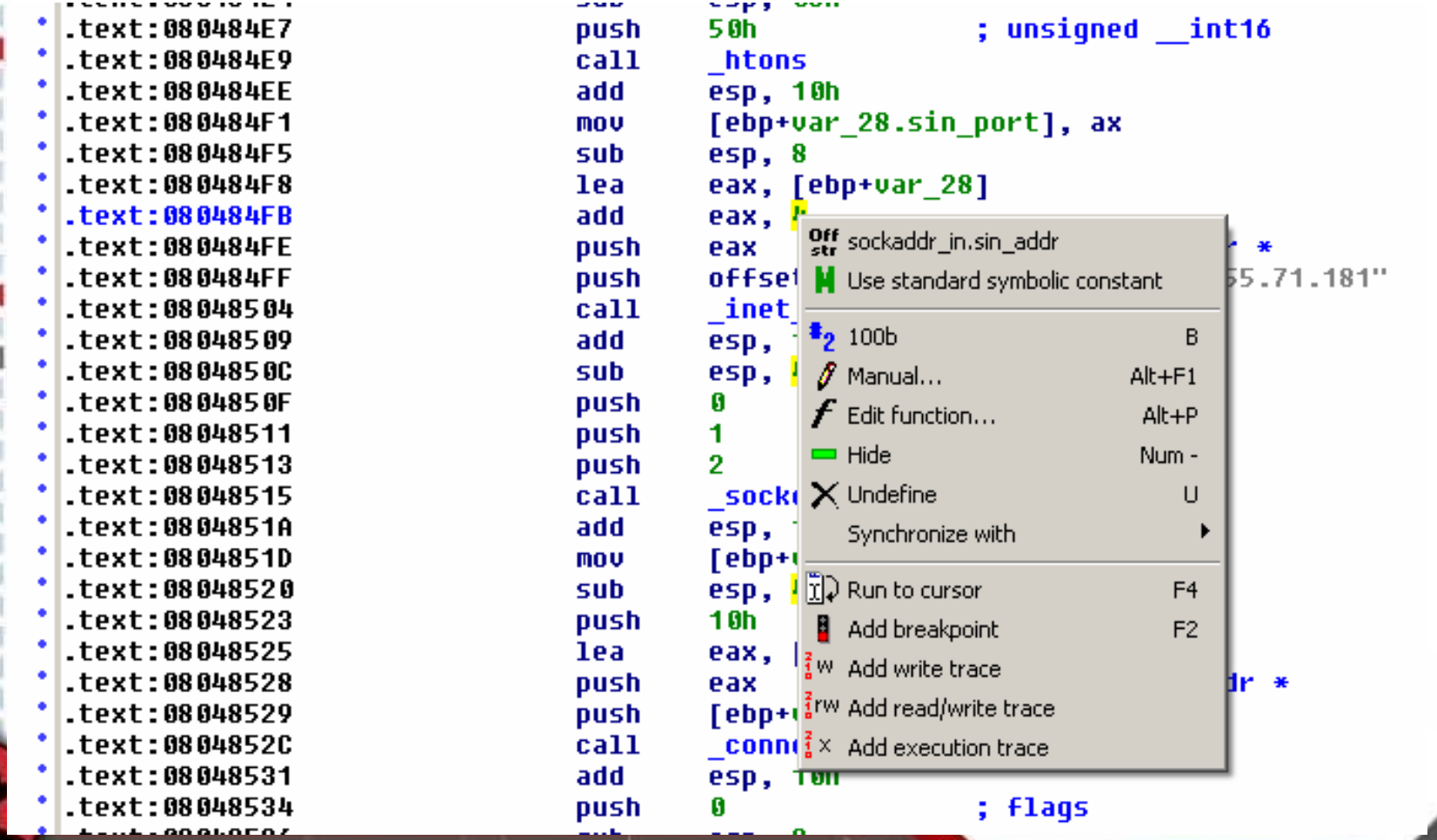
- In your disassembly, struct field names are now available for cleaning up structure member access
- Ida will apply names where it can
- You can right click on constant values to change numbers to a struct field name

# Example (fetch)

- Right click on offset to access struct field renaming options

```
.text:080484D5          push    eax             ; void *
.text:080484D6          call    _memset
.text:080484DB          add     esp, 10h
.text:080484DE          mov     [ebp+var_28.sin_family], 2
.text:080484E4          sub     esp, 0Ch
.text:080484E7          push    50h             ; unsigned __int16
.text:080484E9          call    _htons
.text:080484EE          add     esp, 10h
.text:080484F1          mov     [ebp+var_28.sin_port], ax
.text:080484F5          sub     esp, 8
.text:080484F8          lea     eax, [ebp+var_28]
.text:080484FB          add     eax, 4
.text:080484FE          push    eax             ; struct in_addr *
.text:080484FF          push    offset a205_155_71_181 ; "205.155.71.181"
.text:08048504          call    _inet_aton
.text:08048509          add     esp, 10h
.text:0804850C          sub     esp, 4
.text:0804850F          push    0               ; protocol
```

# Example



# Example (fetch)

```
.text:080484E7                  push    50h             ; unsigned __int16
.text:080484E9                  call    _htons
.text:080484EE                  add     esp, 10h
.text:080484F1                  mov     [ebp+var_28.sin_port], ax
.text:080484F5                  sub     esp, 8
.text:080484F8                  lea     eax, [ebp+var_28]
.text:080484FB                  add     eax, sockaddr_in.sin_addr
.text:080484FE                  push    eax             ; struct in_addr *
.text:080484FF                  push    offset a205_155_71_181 ; "205.155.71.181"
.text:08048504                  call    _inet_aton
.text:08048509                  add     esp, 10h
.text:0804850C                  sub     esp, 4
.text:0804850F                  push    0               ; protocol
.text:08048511                  push    1               ; type
.text:08048513                  push    2               ; family
.text:08048515                  call    _socket
.text:0804851A                  add     esp, 10h
.text:0804851D                  mov     [ebp+var_C], eax
.text:08048520                  sub     esp, 4
.text:08048523                  push    10h             ; int
.text:08048525                  lea     eax, [ebp+var_28]
.text:08048528                  push    eax             ; struct sockaddr *
.text:08048529                  push    [ebp+var_C]     ; int
.text:0804852C                  call    _connect
.text:08048531                  add     esp, 10h
```

# Type Libraries

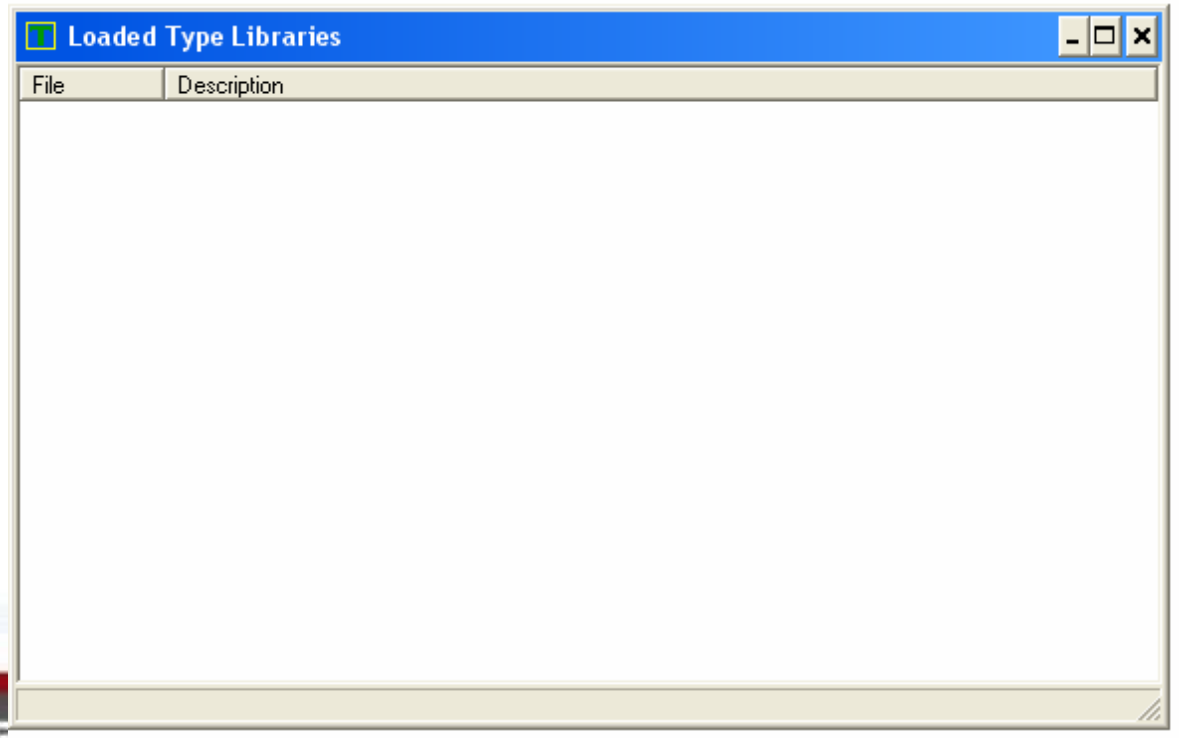
- Ida offers standard data types when it recognizes the compiler used to create the binary
- For Linux/Unix binaries it often fails to recognize the compiler (does better job in 4.9)
  - Thus no data types are offered
- You can force Ida to show you data types
  - View/Open Subview/Type Libraries
  - Which will get you a warning and an empty window

# Type Library Example

- Close the fetch demo, choosing the "DO NOT SAVE" option in the close dialog
- Reopen demos/fetch
- Choose
  - View/Open Subview/Type Libraries

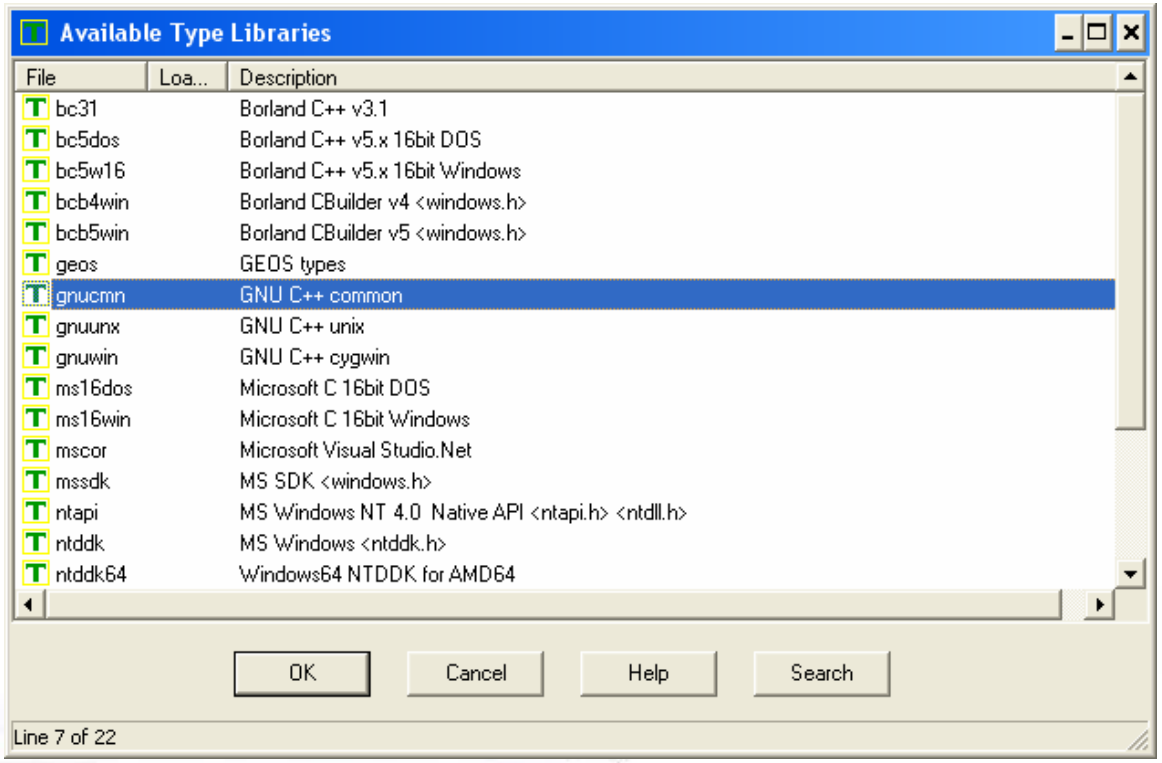
# Type Libraries (cont)

- Press the insert key to add a library
  - 4.9 users will see an entry here already



# Type Libraries (cont)

- Choose an appropriate library (GNU C++ unix)

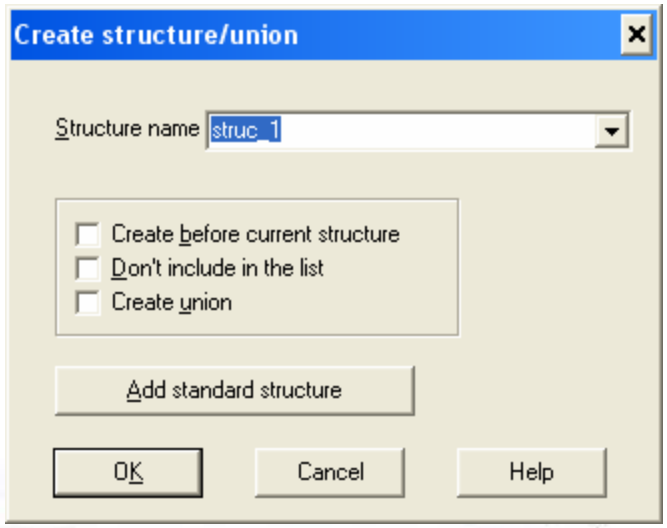


# Type Libraries (cont)

- Once a type library is selected, Ida will apply function signatures from the library to your disassembly
- Note the change in the disassembly listing (versions < 4.9)
- Try to change the type of var_28 from sockaddr to sockaddr_in

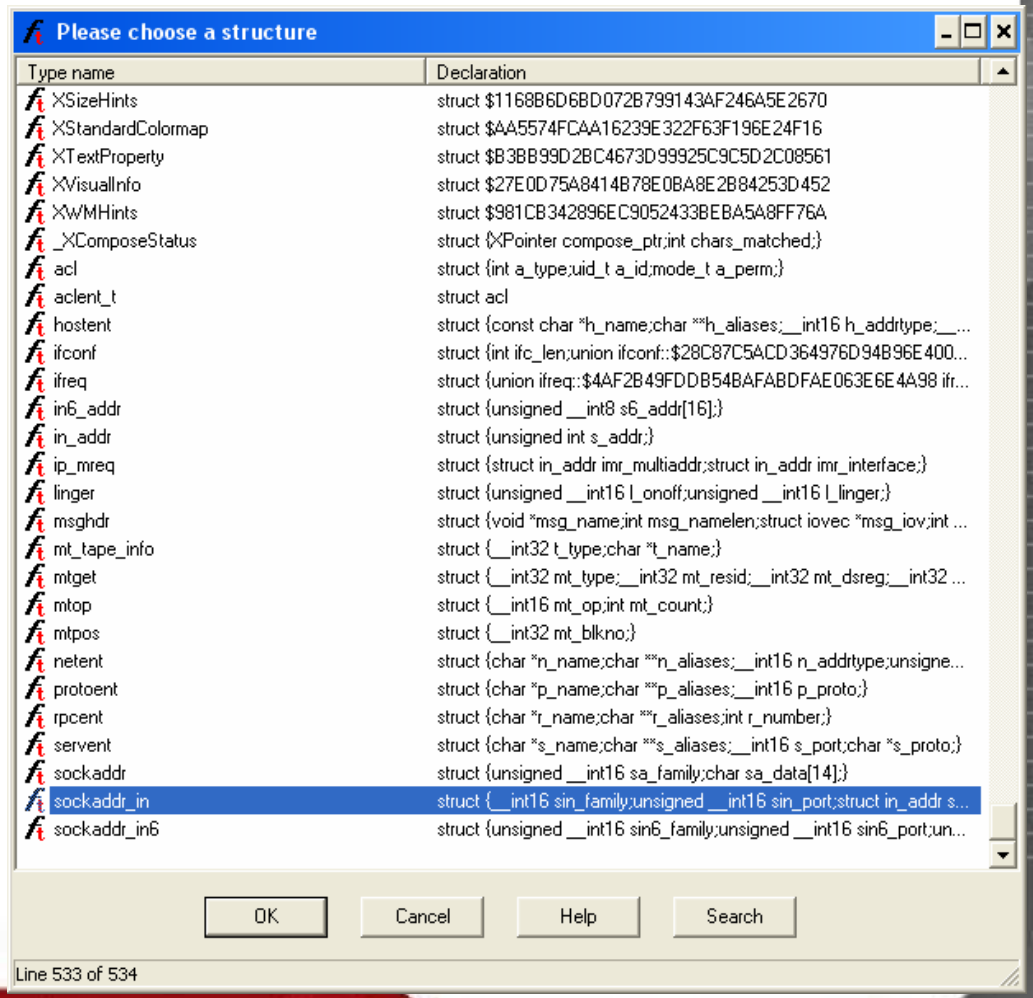
# Adding a Standard Struct

- Navigate to the Structures window
- Press the insert key and choose "Add standard structure"



# Choosing a Standard Struct

- Scroll to and highlight the sockaddr_in struct, then click OK



# Change var_28

- Return to the IDA View window
- Double click on var_28 to get a stack frame view
- Highlight var_28
- Use the Edit/Struct_var menu to change var_28 to a sockaddr_in

# Ida Customization Part 1

Black Hat Training

# Basic Configuration

- Ida contains many configuration files in its cfg subdirectory
- Three files of interest
  - ida.cfg
  - idagui.cfg
  - idauser.cfg
    - User specified options (create this yourself)

# ida.cfg

- Many parameters to affect basic behavior
  - Whether to create backups
  - Formatting options
  - Default maximum name length

# idagui.cfg

- Hotkey assignments
  - Can add or change mappings
- Presence or absence of “Patch” submenu
  - DISPLAY_PATCH_SUBMENU = NO
  - Set to yes for access to patch dialog
    - Allows modification of database bytes

# User Defined Macros

- Ida has a built in scripting language called IDC
- Allows scripting of complex actions
  - Virtually anything you can do with hotkeys or menus
  - Cursor control
  - Opening input dialogs
- We will cover IDC later

# Running Macros

- Macro options
  - Run once via File/IDC Command
  - Save macro as stand alone file and run via File/IDC File
  - Assign macro to hotkey by editing idc/ida.idc
    - This file is executed at Ida startup
- We will do all of these later

# Advanced Binary Analysis

Black Hat Training

# Stripped Binaries

- Contain no symbol table information
- Generally the only names that get recovered are imports
- Look at the difference between demos/proj3a and demos/proj3b for example

# Windows

- Windows binaries import a lot of extra stuff
  - Compare the proj3c, "Debug" version to proj3a
  - Compare the proj3d, "Release" version to proj3b

# Analyzing Statically Linked Binaries

- Statically linked binaries can be challenging
- No import tables
- Large amounts of code
- Most of it is library code
  - Don't want to reverse known library functions
  - Must recognize them somehow

# Statically Linked Binaries

- Linked to library code at build time
  - As opposed to runtime which would be dynamic linking
- Contain no external dependencies
- Usually much larger files
- Much more stuff to sift through
  - See demos/proj3e

# Statically Linked, Stripped Binaries

- Biggest hassle to reverse
  - demos/proj3f
- Difficult to tell user code from library code
  - Could look for syscalls and go from there
  - Much more to libraries than just syscalls
- Ida has a tool to help

# FLAIR

- Fast Library Acquisition for Identification and Recognition
- Examines a library and creates signatures for each exported function
- Then you can match signatures against functions within a binary
- Not well documented
  - See top level readme and sigmake.txt

# FLAIR Installation

- Ida 4.8 users
  - Create a Flair48 subdirectory in your main IdaPro directory
  - Unzip extras/flair48.zip into your newly created subdirectory
- Ida 4.9 users
  - Create a Flair49 subdirectory in your main IdaPro directory
  - Unzip extras/flair49.zip into your newly created subdirectory

# FLAIR Demo

- Copy demos/libc_6.a into your Flair4x/bin directory
- Open a command window and cd into the Flair4x/bin directory
- Our demo library is an ELF binary so we will use the pelf tool

# Creating Flair Signatures

- pelf libc_6.a libc_6.pat
  - Parse the library and create a pattern file
- sigmake libc_6.pat libc_6.sig
  - Create signatures from a pattern file, this will yield errors
- Delete the commented lines at the top of the file libc_6.exc and rerun sigmake
- sigmake libc_6.pat libc_6.sig

# Applying Flair Signatures

- Close IdaPro
- Copy the file libc_6.sig from the Flair4x/bin directory into your <idabase>/sig directory
- Restart IdaPro
- Open demos/proj3f
- Choose file/Load file/Flirt signature file
  - Choose LIBC_6 "Unnamed sample library"
- Many though not all functions are now recognized

# Extending Ida's Capabilities

Black Hat Training

# Ida Scripting

- Scripting in Ida is done using the IDC scripting language
  - C like
  - No data types
  - Declare all variables at beginning of functions
    - No globals
  - Arrays are cumbersome at best, no C style array syntax

# IDC Documentation

- Some help actually included with IDA!
- Look for topics
  - "IDC Language"
    - Expressions
    - Statements
    - Variables
    - Functions
  - "Index of IDC Functions"

# IDC Variables

- Local variables only
- Declare first in function
  - No initialization with declaration
- Not typed
  - **auto** is the keyword that introduces a variable declaration
  - Example

```
auto count, index, i;
```

- Functions generally expect int, float or string data

# IDC Functions

- All are defined with the "static" keyword
- Argument list does not require any type info or the auto keyword
- Return type never specified
  - Just return whatever you want

# Example IDC Function

- Example function

```
static demoFunc(arg1, arg2) {
    auto var1;
    var1 = arg1 * arg2;
    return var1;
}
```

# IDC Expressions

- Use C style operators except op=
- ints promote to floats as required
- + with strings performs string concatenation
- Comparisons work for string operands

```
if ("cat" == "dog") {
```

# IDC Statements

- Most C statements available
  - No switch statement
  - No goto
  - Loops
    - for, while, do all available
    - break and continue available
  - Bracing { } used as in C

# Accessing the Ida database

- Data read functions
  - long Byte(long addr);
  - long Word(long addr);
  - long Dword(long addr);
- Read 1, 2, 4 bytes from indicated database location
  - Address should be a virtual address
- Return -1 if address is invalid
  - Outside any defined program section

# Modifying an Ida Database

- Data writing functions
  - void PatchByte(long addr, long val);
  - void PatchWord(long addr, long val);
  - void PatchDword(long addr, long val);
  - Change 1,2, or 4 bytes at the indicated virtual address
- Useful when working with self modifying code

# Interactive Scripting

- Interface functions
  - void Message(string format, …);
    - Print a message to the message area
    - format is printf style format string
  - void Warning(string format, …);
    - Show a warning dialog box
  - void Fatal(string format, …);
    - Show a fatal dialog box and quit IDA

# Interactive Scripting

- User query functions
  - long AskYN(long default, string prompt);
    - Ask a yes or no question in a dialog box
    - Returns
      - Cancel == -1
      - No == 0
      - Yes == 1
  - string AskStr(string default, string prompt);
    - Ask the user for a string

# Interactive Scripting

- File selection dialog
  - string AskFile(bool forsave, string mask, string prompt);
    - forsave – 0 -> open, 1 -> save
    - mask such as "*.*"
- Several other "Ask" function for requesting various data types

# Cursor Control

- Read current cursor location
  - long ScreenEA();
    - Returns the virtual address of the cursor location
- Jump display to new location
  - long Jump(long addr);
    - Set cursor to indicated virtual address

# Persistant Data

- IDC Arrays
  - The only way to have anything resembling global data
  - long CreateArray(string name);
    - Create a named array, return its "id"
  - void DeleteArray(long id);
    - Clear all elements from and array
  - long SetArrayLong(long id, long idx, long val);
  - long SetArrayString(long id, long idx, string str);
  - string or long GetArrayElement(long tag, long id, long idx);
    - Tag is either AR_LONG or AR_STR

# Script Execution

- File/IDC Command
  - Type or paste IDC commands into an edit dialog
  - Can execute single statements without need to wrap within a function
- File/IDC File
  - Used to execute a stored IDC "program"
    - Program needs a "main" function

# Script Execution

- Macro hotkey execution
  - Create function and save in idc/ida.idc
  - Need not be named main (in fact can't be named main)
  - Use AddHotKey function to map macro to a hot key sequence
    - AddHotkey("Shift-Z", "MyMacro");
    - Add this statement in ida.idc main function

# Example IDC Commands

- Open demos/proj3a
- Double click on the string "SECRET="
- Select File/IDC Command…
- Enter the following

```
auto i, val;
i = ScreenEA();
while ((val = Byte(i)) != '=') {
   PatchByte(i, val + 32);
   i++;
}
```

# Stored IDC Programs

- Must have a "main" function
- Stored programs must

```
#include <idc.idc>
```

- #define is understood as well
- /* … */ or // comments understood

# Uses for Scripts

- De-obfuscating obfuscated code
- Finding and labeling uses of insecure functions
- Analyzing stack frames for presence of stack allocated buffers
- Automatically recognize and create data structures
- Infinite possibilities

# Example IDC Program

- On your CD
  - extras/scripts/n2b_d32.idc
- This script mimics the UPX decompression algorithm to decompress a UPX packed binary
- Also rebuilds import table

# Example IDC Program

- Using Ida, open demos/proj3_upx.exe
- This is a UPX packed executable
  - It IS NOT hostile, but your AV software might think it is
- Position the cursor at start
- Select File/IDC File…
- Open extras/scripts/n2b_d32.idc
- Click through any warnings
- Notice the appearance of many more Names in the Names window
- Right click in the Strings window and choose setup, then Ok

# IDC Programs

- Once you run an IDC program a small "recent IDC scripts" window will appear
- Click on the sheet of paper to edit a script in notepad or the gear to run the script
  - Open n2b_d32.idc in notepad to view the script

# Advanced Scripting

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# IDC Iterator Functions

- IDC offers iterator functions
  - Iterate through code xrefs
    - Rfirst, Rnext, RfirstB, RnextB
  - Iterate through data xrefs
    - Dfirst, Dnext, DfirstB, DnextB
  - Iterate through segments
    - FirstSeg, NextSeg
  - Iterate through functions
    - NextFunction

# IDAPython

- Author: Gergely Erdélyi
- Allows scripts to be authored in Python
- Scripts have access to full IDA API as well as full Python API
- http://d-dome.net/idapython/

# IDA Plugins

- Integrate directly into IDA
  - Essentially a dll that IDA automatically loads
  - Loaded from <ida dir>/plugins when IDA starts
- Compiled C/C++
  - Can access IDA api
  - Can access Windows API
  - Samples provided as Visual C++ projects or gcc makefile

# IDA Plugins

- IDA SDK is required to build plugins
- Essentially no documentation
  - SDK is not supported by DataRescue
- Best, though not great, source of info are the hpp header files in <sdkdir>/include
  - All plugin files should #include <ida.hpp>

# Plugin Writers Guide

- Author: Steve Micallef
- Included on CD
  - docs/ida_plugin_writing.pdf
- Online version at
  - http://www.binarypool.com/idapluginwriting/
- Hyperlinked version at
  - http://www.openrce.org/reference_library/ida_sdk

# Plugin Architecture

- All plugins need an init function
  - Called by IDA at startup
  - Instructs IDA whether to load the plugin or not
- Plugin exports: plugin_t PLUGIN
  - Struct that describes various plugin options including
    - Name of the init function
    - Name of the term(inate) function
    - Name of the run function
    - Desired hotkey to activate the plugin

# Plugin Architecture

- Termination function is called when IDA is closing to offer plugin a chance to cleanup after itself
- Run is called by IDA whenever user enters hotkey sequence
  - Can do just about anything you want here

# Basic Plugin

- Distributed with SDK
- In <sdkdir>/plugins/vcsample
- Demonstrates some basic plugin concepts

# IDA API

- C functions offered that do almost all of the things you can do in the IDC language
  - Unfortunately function names are not always the same
  - Can interact with status window or open basic dialog boxes
- Significantly more functions available for lower level interaction with IDA database

# Plugin Demo

- x86 emulator plugin
- untar extras/ida-x86emu-0.9.tgz into <sdkdir>/plugins
- Shutdown IDA, DO NOT SAVE your proj3_upx.exe work

# Build w/ Visual C++ 6.0

- Using MSCV++, open
  <sdkdir>/plugins/ida-x86emu/x86Emulator.dsw
- Choose Build/build x86emu.plw
- Copy
  <sdkdir>/plugins/ida-x86emu/Debug/x86emu.plw
  To
  <idadir>/plugins

# Build w/ cygwin

- Open cygwin terminal
- cd to <sdkdir>/plugins/ida-x86emu/
- make –f makefile.gcc
- cd to <sdkdir>/plugins/bin
- Copy

  <sdkdir>/plugins/bin/x86emu.plw

  To

  <idadir>/plugins

# Plugin Demo

- Restart IDA
- IDA should load the plugin automatically
- Reopen proj3_upx.exe
- Position the cursor at start
- Type Alt-F8
  - Which happens to be the hot key sequence for the x86emu plugin

# X86 Emulator Plugin

- Provides a virtual CPU
- Allows emulated execution of instructions
- Uses the IDA database as its RAM
  - Provides its own heap and stack
- Fetches instructions from the IDA database and executes them
  - If an instruction modifies other instructions, then the plugin updates the IDA database accordingly

# X86 Emulator Plugin

- Every time an instruction is fetched, the plugin tells IDA to turn that location into code
  - Even if IDA previously thought it was data
  - May require undefining existing instructions
- Useful for working through self modifying code
- Custom dialog boxes can be used in plugins because full Windows API is available

# Collaborative Reversing

- Ida-sync plugin allows multiple users to share work on a single binary
- Client/server architecture
- Server - Python based server
  - Stores user, database, and database change records on central server
- Client – Ida plugin
  - forwards some user actions to server for distribution to other clients

# Vulnerability Scanning

- Halvar Flake's BugScam
  - Set of IDC scripts
  - Iterates through calls to unsafe functions
  - Analyzes arguments to each call for possible unsafe use
  - Generates html reports pointing to possible problems
  - http://sourceforge.net/projects/bugscam

# Vulnerability Discovery with Ida Pro

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# Vulnerability Discovery

- Ida does not automate the vulnerability discovery process
- Its capabilities may make the process easier

# Stack Analysis

- Accurate stack display
  - Required for determining proper placement in return address in exploit buffer
  - Clear picture of what variables may get clobbered during an overflow
- Is there buffer in this stack frame?
- What is the exact distance from the buffer start to overwrite the saved eip?
- What variables lie between the buffer and eip?

# Function Xrefs

- Cross reference lists
  - Clean display of all calls to specified functions
- Xrefs To
  - What are possible execution paths to arrive at a specific location
- Xrefs From
  - Where might this data get passed

# Virtual Address Layout

- Ida acts like a loader when it analyzes a binary for the first time
- Maps the binary to virtual addresses just as actual loaders do
- Easy to determine useful address when write anywhere vulnerabilities are discovered

# GOT Layout

- .got is just another section to ida and easy to view

```
.got:08049764 ; Segment permissions: Read/Write
.got:08049764 _got            segment dword public 'DATA' use32
.got:08049764                 assume cs:_got
.got:08049764                 ;org 8049764h
.got:08049764                 public _GLOBAL_OFFSET_TABLE_
.got:08049764 _GLOBAL_OFFSET_TABLE_ db    ? ;
.got:08049765                 db    ? ;
.got:08049766                 db    ? ;
.got:08049767                 db    ? ;
.got:08049768                 db    ? ;
.got:08049769                 db    ? ;
.got:0804976A                 db    ? ;
.got:0804976B                 db    ? ;
.got:0804976C                 db    ? ;
.got:0804976D                 db    ? ;
.got:0804976E                 db    ? ;
.got:0804976F                 db    ? ;
.got:08049770 off_8049770     dd offset write         ; DATA XREF: _wri
.got:08049774 off_8049774     dd offset fprintf       ; DATA XREF: _fpr
.got:08049778 off_8049778     dd offset __libc_start_main ; DATA XREF:
.got:0804977C off_804977C     dd offset printf        ; DATA XREF: _pri
.got:08049780                 dd offset __gmon_start__
.got:08049780 _got            ends
.got:08049780
```

# Binary Patching

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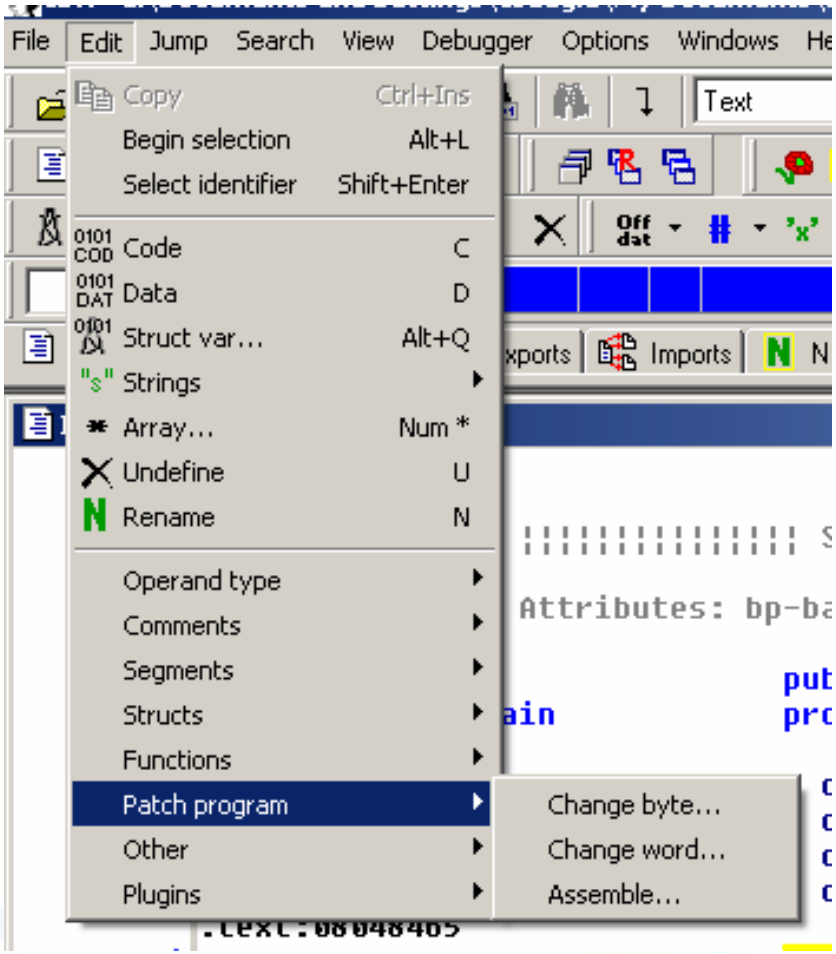
# Why Patch

- Add/Delete/Modify existing behavior
  - Fix vulnerabilities in closed source binary
  - Bypass existing behavior
    - Common among crackers
  - Customize strings
    - Hex editor may be just as easy in this case

# Ida Patching Features

- Patch submenu
  - Enabled by editing cfg/idagui.cfg
    - DISPLAY_PATCH_SUBMENU = YES
- Produce file options
  - File/Produce File submenu
    - Looks promising
      - Especially “Create EXE file …”
        - » Not supported for most formats
    - “Create DIF file …” is best option
      - Non-standard diff format

# Patch Submenu

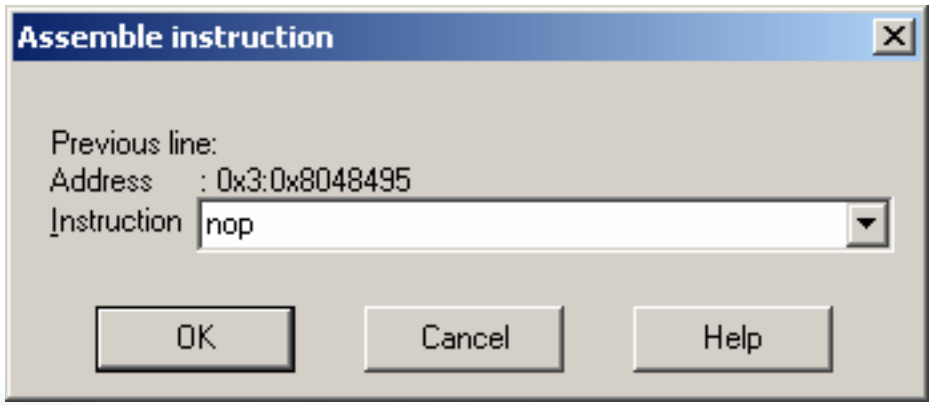


# Using the Patch Submenu

- Change byte and change word are just shortcuts to idc PatchByte and PatchWord functionality
  - Opens dialog to changes values starting at cursor address
- Assemble
  - Opens dialog to enter new instruction at cursor location

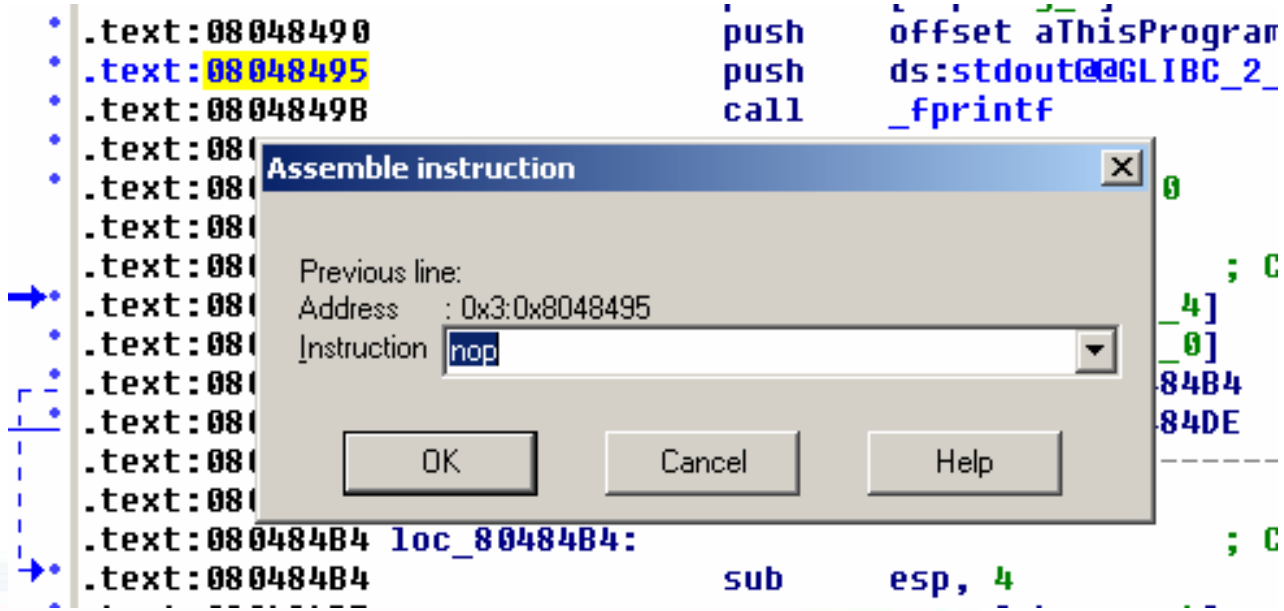
# Assemble Dialog

- Replaces cursor instruction with user specified instruction
  - Users responsibility to make sure instruction alignment is maintained



# Instruction Alignment

- nop below only takes one byte
  - Bytes a 08048496-A remain unchanged



# Ida Dif Files

- Most practical way to export changes
- Only output changes made via PatchByte/Word/Dword
- Simple text file
  - Must apply changes to transform original binary

# Example Ida Dif File

```
This difference file is created by The
  Interactive Disassembler

proj3a
000005C0: 53 73
000005C1: 45 65
000005C2: 43 63
000005C3: 52 72
000005C4: 45 65
000005C5: 54 74
```

# Patching Challenges

- Changing a few bytes is relatively simple
- Careful when changing any relative offset
  - Make sure you compute correct new offset
- Adding code is more challenging
  - Tough to change function calls
    - Must already link to desired function
    - Need space for code to push additional parameters

# Adding Code to a Binary

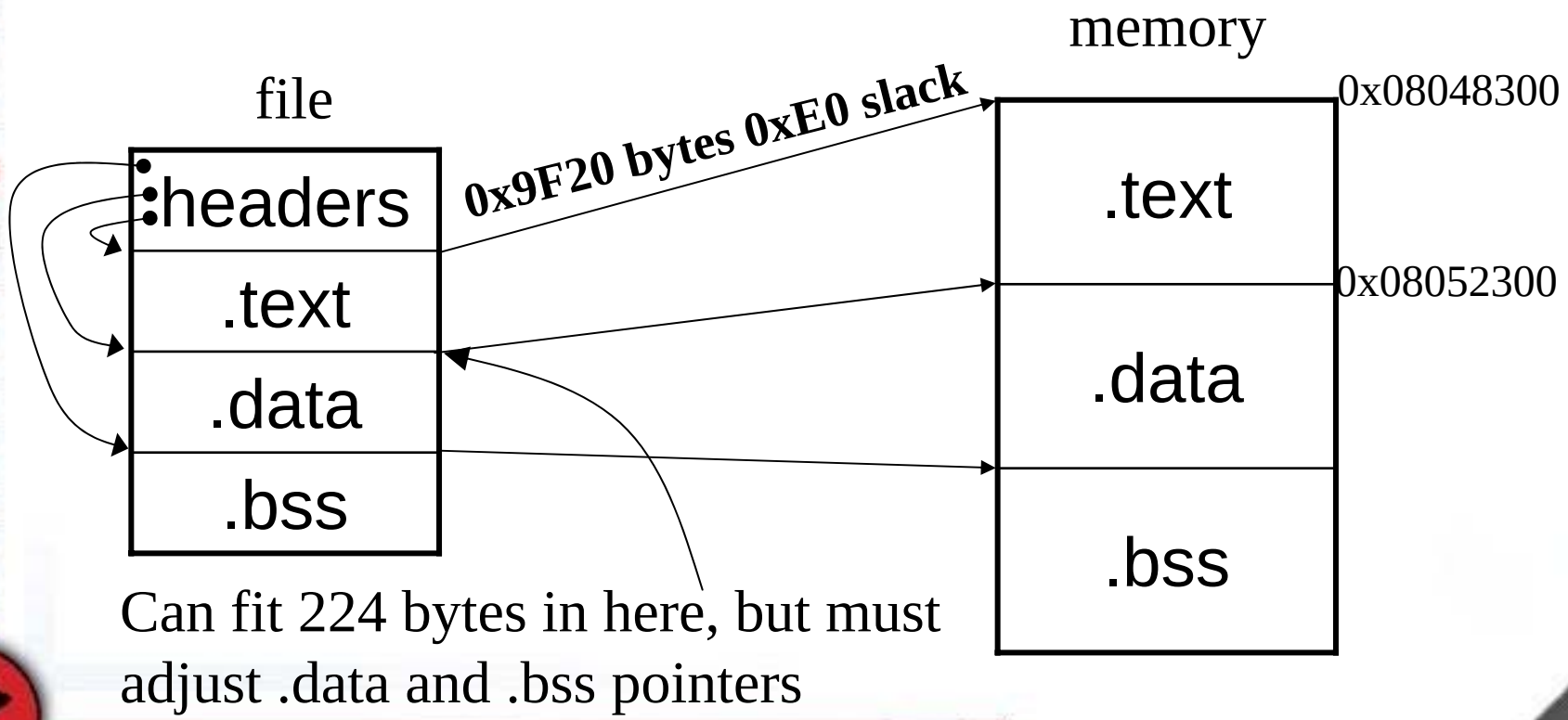
- Can’t simply insert new code
  - Impact on binary file header values
- Moving code changes relative/absolute offsets
  - Must propagate changes through entire binary
- Best option is to patch into available holes

# Binary “Caves”

- Requires detailed understanding of binary format
- Binary sections often have alignment requirements
- Subsequent section must begin with specific alignment
- May offer “slack space” opportunities at end of each section
  - Size on disk vs. size in memory

# Example

- Sections align to 256 byte boundaries



# Analyzing Obfuscated Code

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# Background

- What is obfuscated code?
  - Program transformation to reduce "readability"
    - Performed at source or binary level
    - This talk deals with binary obfuscation
  - Preserves original behavior of program
- Why obfuscate code?
  - Protect intellectual property
  - Hide malicious intent

# Background

- Why analyze obfuscated code?
  - To understand functionality in order to interoperate
  - To access malicious program within for further analysis
  - To understand state of the art in code obfuscation

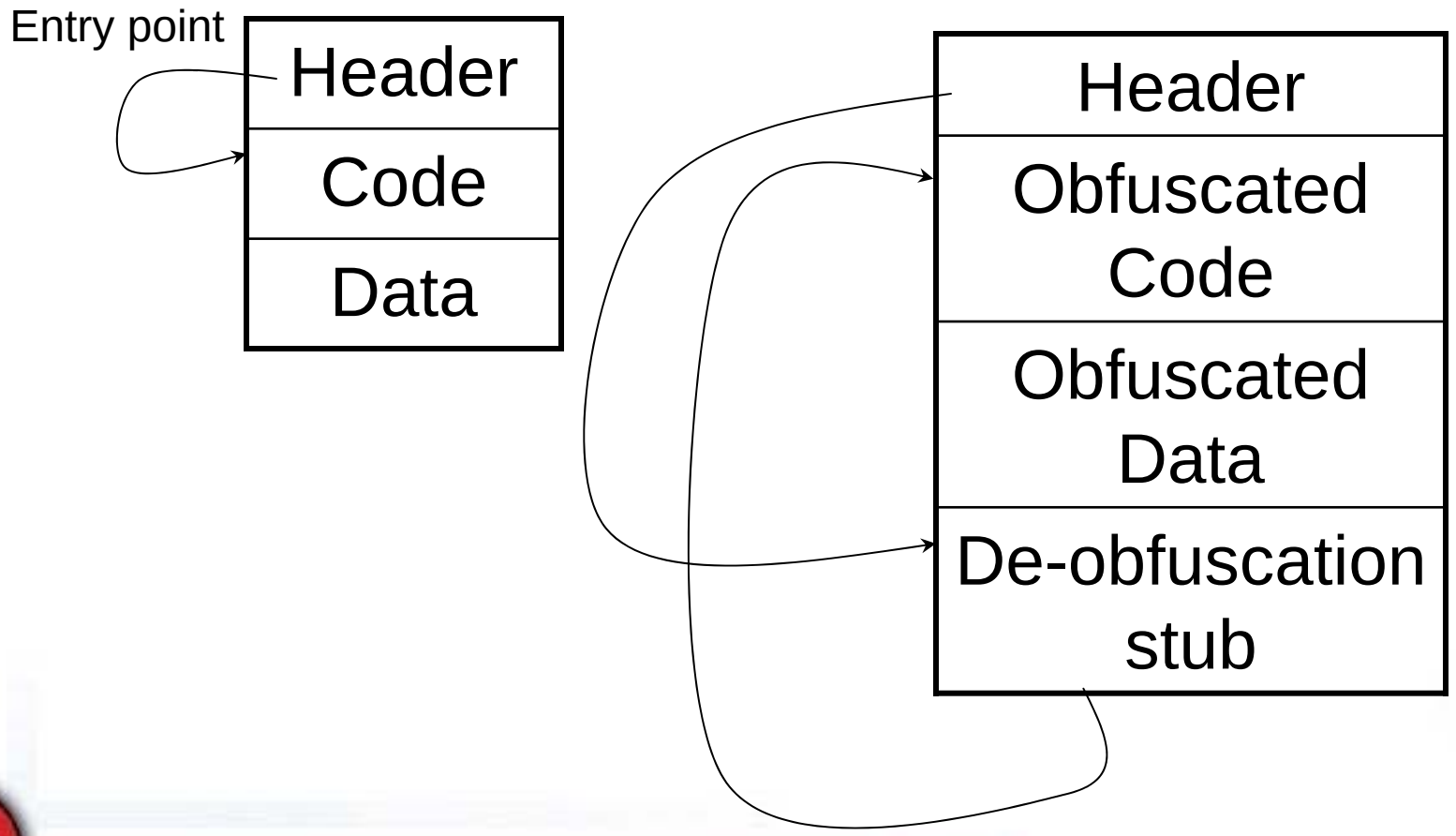
# Obfuscation Basics

- Program written and tested using standard methods
- Compiled program is fed to an obfuscator
- Obfuscator typically "encrypts" the original program
- Obfuscator combines encrypted data block with a "decryption" stub to create a new executable

# Obfuscation Basics

- Program entry point changed to point to decryption stub
- Decryption stub executes and decrypts original binary
- Once decrypted, stub transfers control to original entry point and original binary executes

# Simple Obfuscation

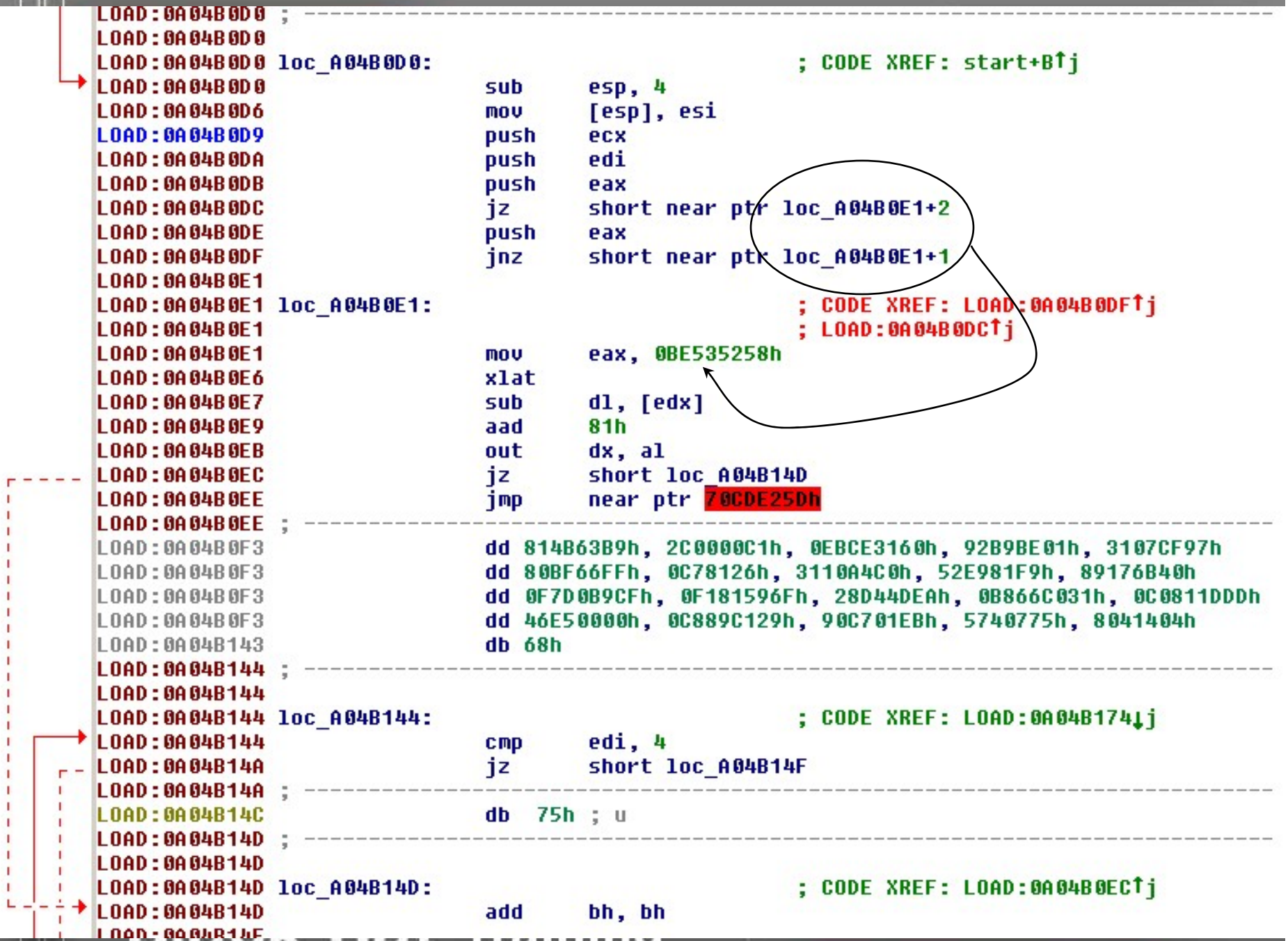


# Types of Analysis

- Black Box/Dynamic
  - Observe the behavior of the program in an instrumented environment
  - Difficult to test all code paths
- White Box/Static
  - Deduce behavior by analyzing the code
  - Requires high quality disassembly
- Hybrid/Gray Box

# Anti-Reverse Engineering

- Anti-disassembly
  - Efforts to prevent proper disassembly
    - Encrypted code
    - Jumps to middle of instructions
      - Violates assumption of sequential execution
- Anti-debugging
  - Debugger detection
  - Timing checks
  - Self-debugging
  - Virtual machiine environment checks



# Anti-Reverse Engineering

- Anti-Analysis
  - Intentional exceptions to modify execution path
  - On demand decryption of code blocks
    - Entire executable is never decrypted at once
    - Defeats memory snap-shotting
  - Instruction replacement/emulation
    - Instructions replaced with software interrupt
    - Interrupt handler does table lookup and emulates the instruction

# Analysis Techniques

- Generally running malicious code is a bad thing
- Static analysis requires a high quality disassembly

# Obfuscated Code Analysis

- Hand tracing assembly language is tedious and error prone
- Anti-reverse engineering techniques obfuscate code paths
- Obfuscated binaries require de-obfuscation before their code can be analyzed

# Obfuscated Code Analysis

- The challenge in static analysis is to get at the obfuscated code
- Essentially need to perform the function of the de-obfuscation stub
- Requires running the code
  - By hand
  - Debugger
  - Emulation

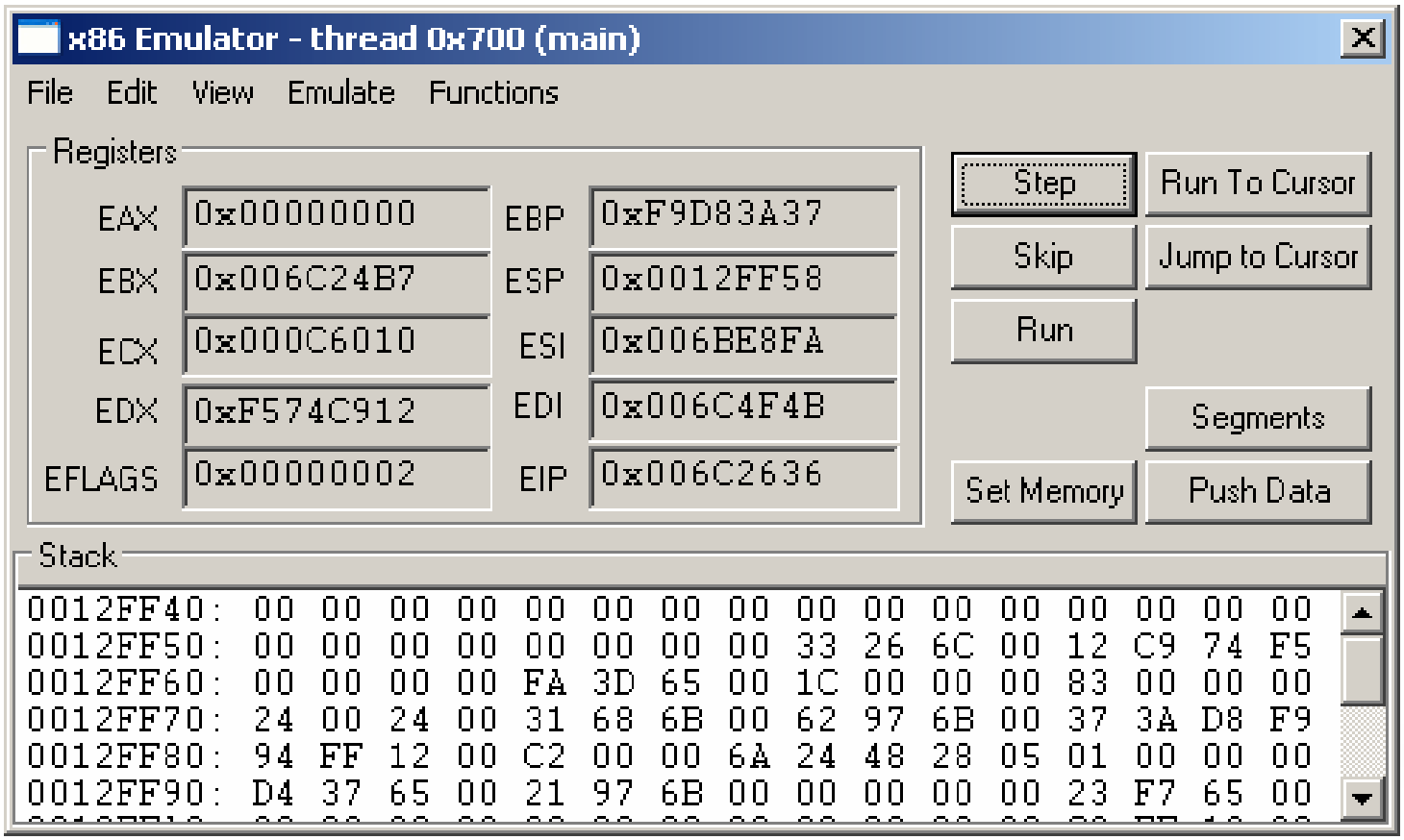
# Static De-obfuscation

- First step – understand de-obfuscation algorithm
- Second step – mimic the algorithm
  - Can be scripted in IDA
    - Requires unique script for each de-obfuscation technique
  - Alternatively mimic the CPU
    - Add an execution engine to IDA

# One Method

- x86 emulator plugin for IDA
- Lightweight emulator
  - Maintains CPU state
  - 'Fetches' instructions by querying IDA database
  - Emulates the instruction
  - Updates IDA database if required
    - Self modifying code for example

# Emulator Console



# Results

- No need to develop scripts or even perform detailed analysis of de-obfuscation layer
  - The emulator is the script
- Allows safe, automated unpacking/decrypting of "protected" binaries
  - UPX, burneye, shiva, tElock, ASPack, …

# Emulator Features

- Similar to a debugger in many ways
- IDA database serves as instruction and static data memory space
- Emulator supplies its own stack space
- Emulator supplies its own heap
  - Redirect library functions to plugin provided equivalents

# Emulator Memory

- Code and static data must be fetched from IDA database
- Other references must be directed to either stack or heap
  - Every memory reference checked
  - Could easily add comprehensive memory usage analysis

# Limitations

- Slow
  - Because of emulated execution and IDA interactions
- Instruction set emulator only
  - Not an O/S emulator
  - Can't follow calls into dynamically linked functions
  - Can't follow system calls in statically linked functions

# O/S Interface Issues

- Generally need to provide some basic services to the de-obfuscation routine
  - Memory allocation
  - Exception handling
  - Linking services
- Minimal set of functions provided by the plugin
  - Heap management
  - Windows Exception Frames

# Morphine Demo

- Morphine is an obfuscator used on some windows rootkits
- Available in demos/rootkit/avg.exe
  - Load into IDA
  - Use emulator to unpack and extract

# Contact Info

- Chris Eagle
  - cseagle@redshift.com

# Resources

- IDA Downloads

  http://www.datarescue.com/idabase/idadown.htm

  – Halvar Flake's structure reconstructor

    http://www.datarescue.com/freefiles/strucrec.zip

- Interesting IDC scripts

  – Halvar Flake's script based "security scanner"

    http://sourceforge.net/projects/bugscam

    - Scans for use of strcpy, printf, etc

- x86 Emulator plugin

  – http://sourceforge.net/projects/ida-x86emu

# References

- Pentium reference manuals
  - http://developer.intel.com/design/Pentium4/documentation.htm#manuals
- Others on CD in docs directory
  - File format references
- API references are always handy
  - MSDN
    - http://msdn.microsoft.com/library/default.asp