An Introduction to Reverse Engineering with IDA

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1 Introduction

IDA and IDA Pro are disassemblers that will make your life much easier when it comes to disassembling executables as well as understanding the underlying code. IDA, short for *Interactive DisAssembler*, allows a reverse engineer to not only see disassembled code, but to modify it in such a way to make understanding the disassembly much easier at a glance. IDA will attempt to identify variables while allowing a reverse engineer to rename variables and functions as well as propagating those changes throughout the disassembly. IDA even allows the user to make comments on the disassembly.

IDA allows for disassembly of not only x86 binaries–it supports a number of other architectures such as ARM, MIPS, and others. Many CTFs will provide challenges for somewhat esoteric architectures, and we need a tool that can handle those. If a particular architecture is unsupported by IDA, it provides for a rich plugin interface that would allow us to write add-ons to handle that architecture.

Finally, IDA has a well-integrated debugging system that allows for debugging on the local host as well as providing an interface for remote debugging such as that which can be done with *gdbserver*.

2 IDA in CTF

For our purposes, IDA is an invaluable tool for both reverse engineering and exploitation exercises. We will use it for disassembly, local and remote debugging, and CTF vulnerability research/exploit development.

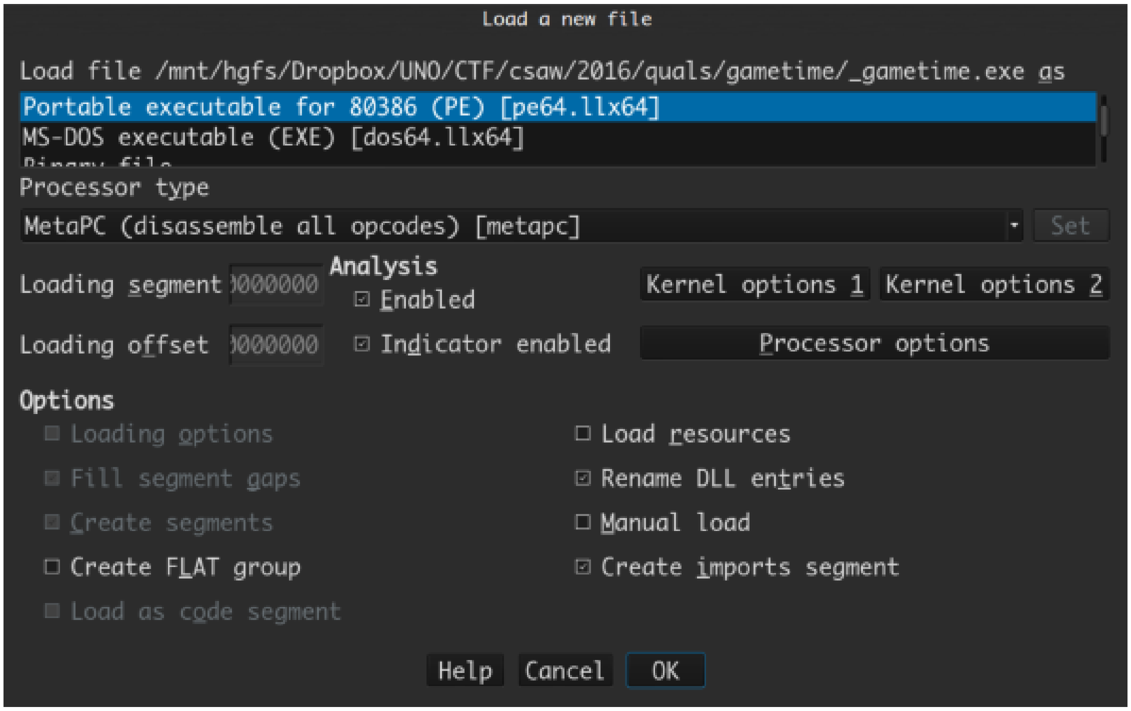
3 Opening IDA and loading a file

Go ahead and open IDA. If you're not sure whether you need to open the version for 32 or 64 bit binaries and you have IDA Pro, open the 64-bit version.

Immediately you may see a box with information about the IDA license. Click OK or ignore it, and you'll see a box with three options: new, go, and previous. "New" will prompt you to open a binary to disassemble. "Go" will open IDA to a blank interface. "Previous" will allow you to open a previous IDA database listed in the menu below.

Go ahead and choose "New". You have been provided with a file titled "gametime.exe". This is part of a challenge from the CSAW CTF 2016 qualification event. Navigate to and open this file.

At this point, you should run the executable for testing–if on Windows, you should be able to run it natively. If you're on Linux or MacOS, you'll need to run it either through a translation layer such as Wine or through a virtual machine running Windows. You'll notice that it's a simple game that requires prompted well-timed keypresses to play and win.



Load a new file

Load file /mnt/hgfs/Dropbox/UNO/CTF/csaw/2016/quals/gametime/_gametime.exe as

Portable executable for 80386 (PE) [pe64.llx64]
MS-DOS executable (EXE) [dos64.llx64]
Binary file

Processor type
MetaPC (disassemble all opcodes) [metapc]

Loading segment)000000
Loading offset)000000

Analysis
☑ Enabled
☑ Indicator enabled

Options
■ Loading options
■ Fill segment gaps
■ Create segments
□ Create FLAT group
■ Load as code segment
□ Load resources
☑ Rename DLL entries
□ Manual load
☑ Create imports segment

Figure 1: IDA file loading screen

Back to IDA, you'll see a window that should look similar to Figure 1 above. The list at the top of the window allows you to pick an IDA loader for the file type that IDA has detected (such as a PE file, in this case), or you can choose to simply load the file as data, in which case IDA will not parse it to find code sections, data, etc–if you require, you would need to do this yourself. However, if it's not already selected, choose the PE (Portable executable for 80386) option.

Secondly, you'll be able to select the processor type. IDA should have automatically selected MetaPC. This is fine in this case, however, depending on your file type, and whether or not IDA has been able to automatically determine the file type and processor, you may need to select a particular processor type for your binary such as ARM, MIPS, Motorola 6803, etc. If MetaPC has not been selected, choose that option.

Those are the two primary options–we need not select any others, but we'll describe some others. Depending on how executables are normally loaded on their system, you may need to adjust the loading segment and offset such that IDA displays and interprets the executable as being loaded into a particular area of memory. If you were to disable program analysis, IDA would not disassemble the program code or populate subroutine listings, variables, or other attributes. With "manual load", you are given more options in loading such as where to base the file, which sections of the file to load, etc. You can choose to specifically load resources such as images into the IDA database (something you might wish not to do depending on size and relevance to the disassembly).

Other options in the loading prompt you may need to understand for other files, but for now, we'll move on. Go ahead and click "OK". IDA will proceed to load the file.

4 Taking an initial look at the disassembly

When it loads, you should see a sidebar that contains function names on the left side. If you don't see it, typing "Shift+F3" should open a function window. While the number of functions makes this executable look huge, you can find the core logic of most compiled executables in the main function. In this case, the function should be titled "_main", and should be near the top of the sidebar. If not, click on a function within that sidebar, and hit Alt+t to search for "_main". Once you find it, double-click on it, and main's code should be visible within the main window.

If the main window shows a simple linear code listing rather than a graph, click within the primary window and hit the spacebar. At this point, you should see a graph view, which can be particularly helpful for visualizing a program's control flow. Each function has its own code graph, and the blocks within are divided by code jumps. For conditional jumps, the green (or other, you may need to check settings) arrow should point to target blocks for which the jump is taken, and the red arrow points to blocks for which the jump is not taken (if viewing a simple code listing, the red arrow targets should generally immediately follow the conditional jump).

You'll notice that at the top of the function, IDA has given you its guess as to main's parameters. It has also enumerated a number of local variables and arguments based upon patterns of stack allocation and local memory access. As mentioned before, you can change the names of these variables and arguments as you see fit, and the changes should propagate throughout the scope of these variables and arguments within this function as well as possibly outside (for function calls).

Scroll through the code for _main, taking note of the various strings referred to by various offsets pushed to the stack–these strings will be partially visible in the graph through automatically populated comments, so you don't need to follow the offsets to read the strings like you would in a debugger like GDB.

At this point, you may want to run gametime.exe again. Take a note of the strings that you see as you play through it, and see if you can see any of those strings in the main function–they are there. Also, note that many of these strings are pushed to the stack as arguments to one particular function. Marked "sub_401A73" in the example listing, let's proceed with the assumption that the function at 0x401A73 is a custom print function due to the context of its usage. Assumptions such as this can be dangerous to make (especially in malware analysis), but remember that we're competing in a CTF, and must make the best of our time.

While remaining in the main function, click on any line that calls sub_401A73, making sure that you click on the particular part of the line that says "sub_401A73". Now hit the "n" key. A box will pop up that asks for a new name for the function, so let's call it "custom_print". Type that into the box and click "OK". You'll note that every reference to that function (within main and elsewhere) now refers to it by "custom_print" rather than "sub_401A73". Now you'll no longer need to remember the function by the old name, and scanning through code that frequently references that function should be much easier.

5 Searching the database

We could continue to disassemble the main and other functions to better nail down functionality, but again, we're short on time. While playing gametime.exe, you may have noticed a particular string pop up on failure: "UDDER FAILURE!" with a link. Let's find where that string pops up in the program. We need to navigate to the *strings* subview. To find it, you can either type "Shift+F12" or click on the View menu, mouse down to "Open subviews", and then follow that to "Strings".

Once the strings window is up, click somewhere within it, and then type "Alt+t". You should see two separate occurrences of that string. If you don't see the second, typing "Ctrl+t" will continue a prior search, and you should see the second occurrence. Double-click on one, and IDA will navigate to it in the executable, in the .rdata section. Following the string, you'll see a note that there's a cross reference, referencing it as data: "DATA XREF: sub_...". Double-clicking on the name of the subroutine will take you to the reference to the string in code.

6 Patching the database

If you follow both occurrences of the string to their cross references, you'll notice that both lie in a block of code following a conditional jump. They're being pushed as arguments to the custom print function, so evidently the preceding conditional jump has resolved for the failure condition. What if we switch these?

While many reverse engineering challenges require the solver to RE code that will dynamically build the flag based upon user input, that may not always be the case. If that is the case here, our job is made more difficult. To save time, let's proceed initially with the assumption that nothing is calculated from our input, and that the program simply checks to see if we provided the right input at the right time.

So if that's true, then all we need to do might be to simply force control flow into the success block–we can do so by flipping the conditional or changing it to an unconditional jump into the correct block.

If you're not looking at one of the pushes of an "UDDER FAILURE!" string, navigate back to one now. Click on the line of the conditional jump that precedes the "UDDER FAILURE" block of code. Now click on the Edit pulldown menu at the top, and mouse over "Patch program". Within that submenu, click on "Assemble...". A window should pop up with a text box containing the jump instruction. Changing the conditional jump mnemonic either to its opposite to force success upon failure of hitting the right key in time or to "jmp" should accomplish our goal. Hit "OK". If you have the assembly listing up you should notice the change in the code, and if you have the graph view up, you'll see that the graph has rearranged itself, and the failure block will likely now be missing. If the "Assemble instruction" menu remained up after hitting "OK", clicking "Cancel" should close the window while leaving the change intact.

Don't forget now to make the same change to the other occurrence of "UDDER FAILURE!"!

Click on the Edit menu again, mouse through "Patch program", and click on "Apply patches to input file...". This will bring up a dialog box. Before clicking "OK", you may want to make a copy of the executable, or check the "Create backup" box to do the same in IDA. Once you've backed up the original executable, clicking "OK" will write the changes to the executable.

7 Capturing the Flag

Now run the executable again. Depending on how you patched it, pressing keys may not matter (though if you reversed the conditional, you may just want to keep your hands off the keyboard). Wait a while, and eventually the flag is output–it's a non-standard flag format for this competition, but you'll know the right one.

8 Keyboard Shortcuts

Provided is a table of useful shortcuts. Many of these are not touched upon, and some of them (particularly keys used for commenting the disassembly) are vital functions.

Task	Command
Comment a line	`:`
Add repeatable comment (will propagate to anything referencing that line)	`;`
Search current subwindow	`Alt+t`
Continue search	`Ctrl+t`
View cross-references to item at cursor	`x`
Convert data at point to code	`c`
Undefine at point	`u`
Rename	`n`
Convert at point to data	`d`
Convert at point to ASCII string	`a`
Jump to address	`g`

For more function shortcuts, functions available in the IDA pulldown menus with shortcuts will generally show the shortcut in the menu. For example, there are a myriad of search types available in the Search pulldown menu, and almost each has its own shortcut.