Debugging Using Radare2... and Windows!

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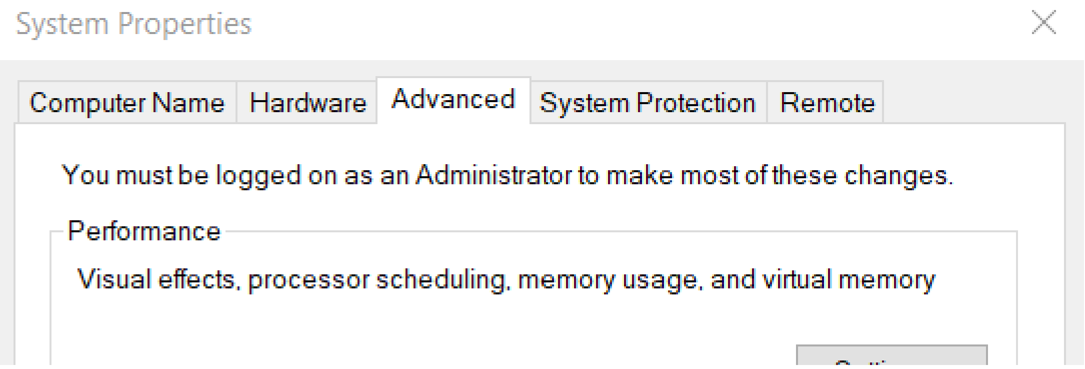
Feb 27, 2018 · 8 min read

To start off I want to say I am a Linux person. I use it all the time for development. The command-line is amazing and very streamlined for computer-science related tasks. While I feel this way, there are those who do not and would prefer to use a Windows environment instead. So I want to show two things in this article, how to install and use radare2 for Windows, and also how to debug applications using radare2.

To get radare2 installed on Windows I went to their site and clicked on the "Download 2.3.0 for Windows" link that is at the top of the page. Then you simply run the installer and radare2 should be on your system! The problem was that all the installer did was drop the radare2.exe as well as the other tools in my C:/users/username/AppData directory. I would have to change directory into that folder from the command line in order to use the executables. In order to access the file from anywhere in the command line you will have to add the directory to your $PATH environment variable. This is just a variable your computer uses in order to find commands and applications you can run from anywhere on the system.

To change your $PATH variable you can do it one of two ways. You can use the Windows GUI to change it by going to System Properties -> Advanced -> Environment Variables, click on the Path variable and click Edit. Then you can add the directory leading to your radare2 files.

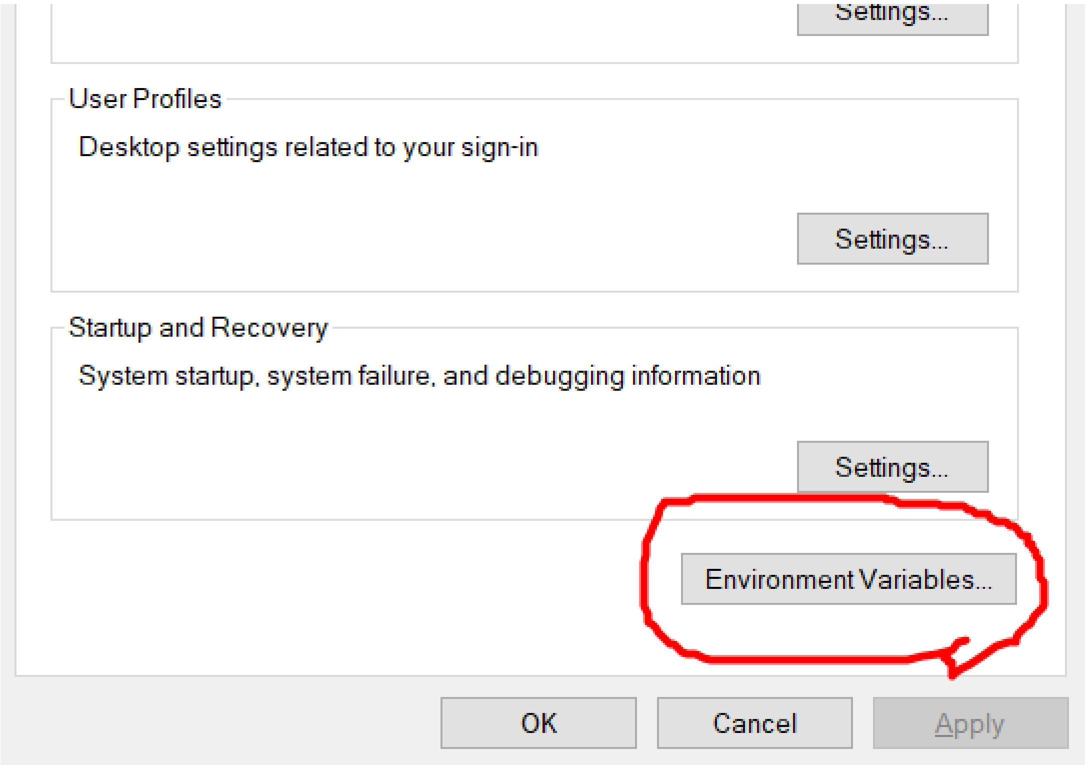


System Properties

You must be logged on as an Administrator to make most of these changes.

Performance

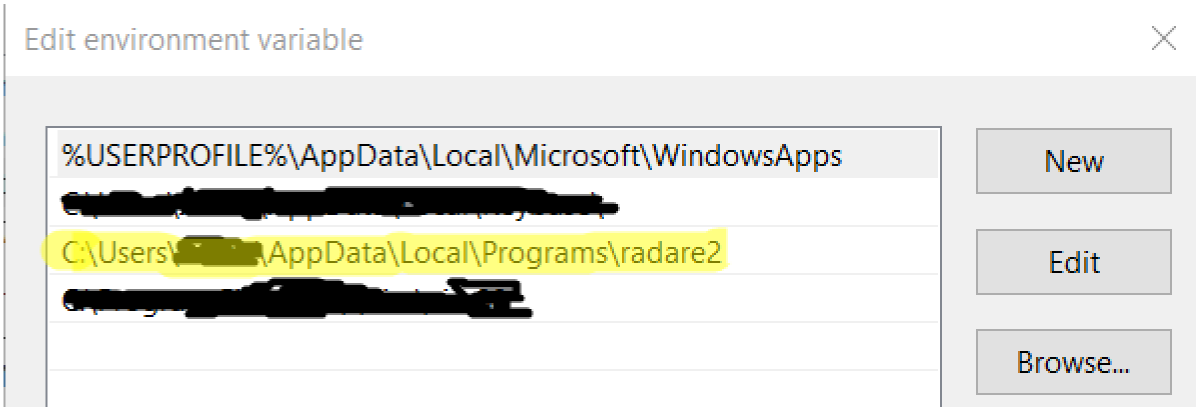
Visual effects, processor scheduling, memory usage, and virtual memory



Desktop settings related to your sign-in

System startup, system failure, and debugging information

System Properties to View and Edit Environment Variables



%USERPROFILE%\AppData\Local\Microsoft\WindowsApps
[redacted]
C:\Users\[redacted]\AppData\Local\Programs\radare2
[redacted]

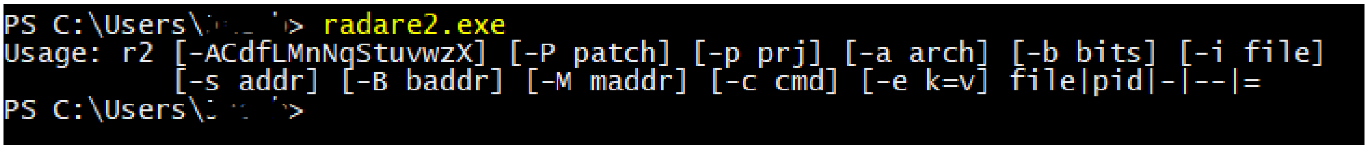
Editing the Path Environment Variable

You can also be super 1337 and do it from the command line. The way to do this would be to open up PowerShell as administrator and use the command

```
[Environment]::SetEnvironmentVariable("Path", $env:Path + ";C:\Users\
<username>\AppData\Local\Programs\radare2",
[EnvironmentVariableTarget]::Machine)
```

This command makes it so that you do not have to add the folder to your $PATH variable every time you reboot your computer.

Now if you run the command radare2.exe you should see radare2's help message. Meaning that you have successfully installed radare2 on your system.



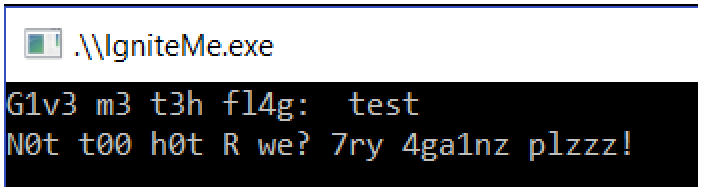
```
PS C:\Users\[redacted]> radare2.exe
Usage: r2 [-ACdfLMnNqStuvwzX] [-P patch] [-p prj] [-a arch] [-b bits] [-i file]
          [-s addr] [-B baddr] [-M maddr] [-c cmd] [-e k=v] file|pid|-|--|=
PS C:\Users\[redacted]>
```

Proof that Radare2 was successfully installed

Now that we have Radare2 installed we can move on to our tutorial on debugging. If you do not know what debugging is, it is essentially running the program and pausing at each assembly instruction. It allows you to see dynamically what is going on under the hood and is often times easier than static analysis. However when analyzing malware it is safer to perform static analysis since the file is not actually running. If you want to debug malware, since it is an important part of the analysis process, then you should do it in a Virtual Machine.

I will be demonstrating how to solve Challenge 2 for the Flare-On 4 Capture the Flag challenge. The Flare-On challenge is an annual Reverse Engineering competition hosted by FireEye. I highly recommend anyone interested in Reverse Engineering to at least try it out as you can learn a lot from it. You can download the binaries from last year's challenge from their site.

We should start by running the program to see what it expects from us and go from there. When we boot up the program we see it prompts us for a password. If we try to guess the password we are shown a message telling us that we are wrong. Not too complex, we just need to find out what the password is.



```
G1v3 m3 t3h fl4g:  test
N0t t00 h0t R we? 7ry 4ga1nz plzzz!
```

Output of the challenge binary

I'm going to run the binary through rabin2 to pull out basic information. I went over how to do this back in my first article detailing how to use radare2.

```
arch     x86
binsz    3072
bintype  pe
bits     32
canary   false
class    PE32
cmp.csum 0x00000e67
compiled Fri Jul 31 17:44:07 2043
crypto   false
endian   little
havecode true
hdr.csum 0x00000000
linenum  false
lsyms    false
machine  i386
maxopsz  16
minopsz  1
nx       false
os       windows
overlay  false
pcalign  0
pic      false
relocs   true
signed   false
static   false
stripped true
subsys   Windows CUI
va       true
```

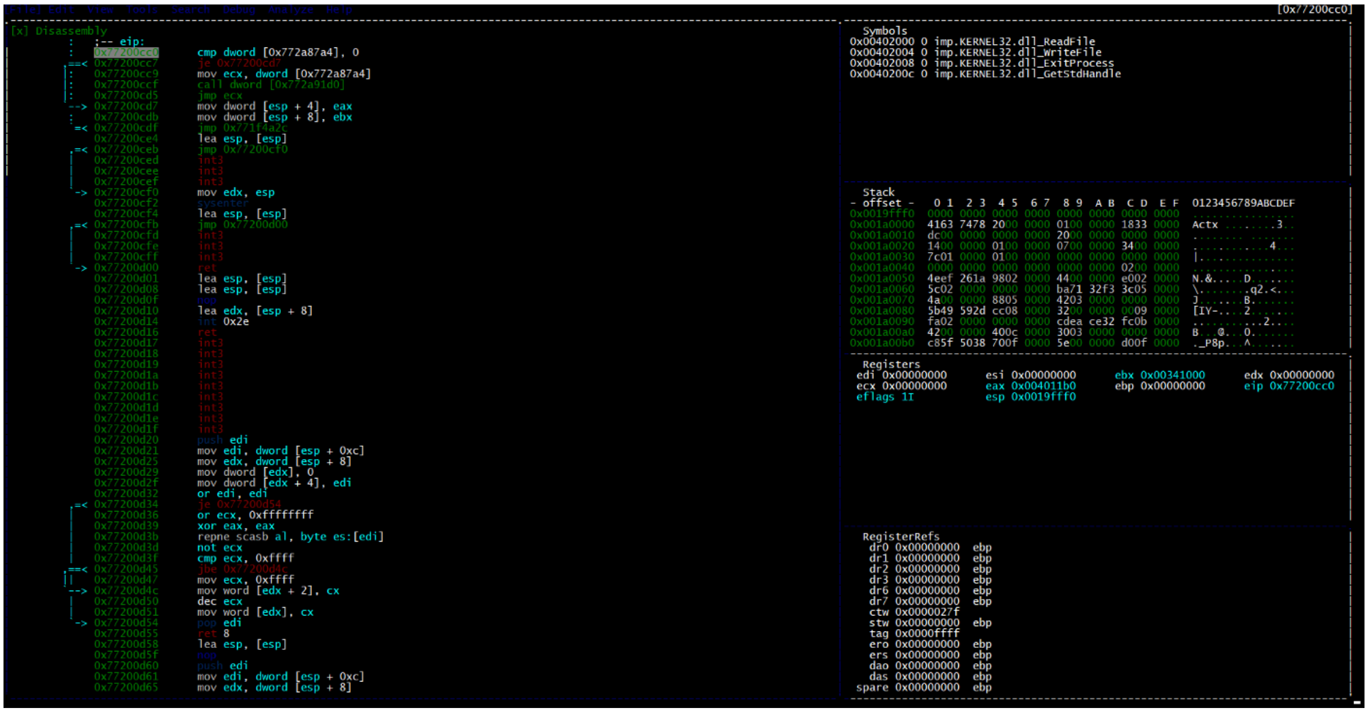
There is nothing too interesting here, so we'll take a look at the strings and see what we got.

```
\r├äΓÇ╝αá╝
GetStdHandle
ReadFile
WriteFile
ExitProcess
KERNEL32.dll
\r&IE*
xD+l]^E
+DonV\t_EGs&\n\r
G1v3 m3 t3h fl4g:
G00d j0b!
N0t t00 h0t R we? 7ry 4ga1nz plzzz!
```

Nothing overly interesting here either. We see the string “G00d j0b!” which is probably what we get when we guess the flag correctly. The rest of the information looks like a lot of jumbled garbage, so the password is probably encrypted. We’ll have to debug the application in order to find out how we compare our password to their encrypted one. Open up the application in radare2 using the -d flag which tells radare2 that we are going to be debugging this application.

```
> radare2.exe -d IgniteMe.exe
[0x77200cc0]>
```

From here we analyz the executable using the command ‘aaaa’. Then we jump into radare2’s special visual mode for debugging by using the command ‘V!’. This mode allows us to see the stack, registers, and other information all from one window.

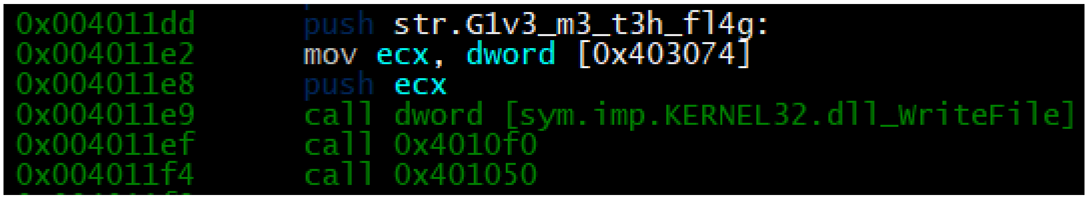


```
[x] Disassembly
            ;-- eip:
            0x77200cc0      cmp dword [0x772a87a4], 0
        ,==< 0x77200cc7      je 0x77200cd7
        |:   0x77200cc9      mov ecx, dword [0x772a87a4]
        |:   0x77200ccf      call dword [0x772a91d0]
        |:   0x77200cd5      jmp ecx
        `--> 0x77200cd7      mov dword [esp + 4], eax
         :   0x77200cdb      mov dword [esp + 8], ebx
         `=< 0x77200cdf      jmp 0x771f4a2c
             0x77200ce4      lea esp, [esp]
         ,=< 0x77200ceb      jmp 0x77200cf0
         |   0x77200ced      int3
         |   0x77200cee      int3
         |   0x77200cef      int3
         `-> 0x77200cf0      mov edx, esp
             0x77200cf2      sysenter
             0x77200cf4      lea esp, [esp]
         ,=< 0x77200cfb      jmp 0x77200d00
         |   0x77200cfd      int3
         |   0x77200cfe      int3
         |   0x77200cff      int3
         `-> 0x77200d00      ret
             0x77200d01      lea esp, [esp]
             0x77200d08      lea esp, [esp]
             0x77200d0f      nop
             0x77200d10      lea edx, [esp + 8]
             0x77200d14      int 0x2e
             0x77200d16      ret
             0x77200d17      int3
             0x77200d18      int3
             0x77200d19      int3
             0x77200d1a      int3
             0x77200d1b      int3
             0x77200d1c      int3
             0x77200d1d      int3
             0x77200d1e      int3
             0x77200d1f      int3
             0x77200d20      push edi
             0x77200d21      mov edi, dword [esp + 0xc]
             0x77200d25      mov edx, dword [esp + 8]
             0x77200d29      mov dword [edx], 0
             0x77200d2f      mov dword [edx + 4], edi
             0x77200d32      or edi, edi
         ,=< 0x77200d34      je 0x77200d54
         |   0x77200d36      or ecx, 0xffffffff
         |   0x77200d39      xor eax, eax
         |   0x77200d3b      repne scasb al, byte es:[edi]
         |   0x77200d3d      not ecx
         |   0x77200d3f      cmp ecx, 0xffff
        ,==< 0x77200d45      jbe 0x77200d4c
        ||   0x77200d47      mov ecx, 0xffff
        `--> 0x77200d4c      mov word [edx + 2], cx
         |   0x77200d50      dec ecx
         |   0x77200d51      mov word [edx], cx
         `-> 0x77200d54      pop edi
             0x77200d55      ret 8
             0x77200d58      lea esp, [esp]
             0x77200d5f      nop
             0x77200d60      push edi
             0x77200d61      mov edi, dword [esp + 0xc]
             0x77200d65      mov edx, dword [esp + 8]
```

```
 Symbols
0x00402000 0 imp.KERNEL32.dll_ReadFile
0x00402004 0 imp.KERNEL32.dll_WriteFile
0x00402008 0 imp.KERNEL32.dll_ExitProcess
0x0040200c 0 imp.KERNEL32.dll_GetStdHandle

 Stack
- offset -   0 1  2 3  4 5  6 7  8 9  A B  C D  E F  0123456789ABCDEF
0x0019fff0  0000 0000 0000 0000 0000 0000 0000 0000  ................
0x001a0000  4163 7478 2000 0000 0100 0000 1833 0000  Actx ........3..
0x001a0010  dc00 0000 0000 0000 2000 0000 0000 0000  ................
0x001a0020  1400 0000 0100 0000 0700 0000 3400 0000  ............4...
0x001a0030  7c01 0000 0100 0000 0000 0000 0000 0000  |...............
0x001a0040  0000 0000 0000 0000 0000 0000 0200 0000  ................
0x001a0050  4eef 261a 9802 0000 4400 0000 e002 0000  N.&.....D.......
0x001a0060  5c02 0000 0000 0000 ba71 32f3 3c05 0000  \........q2.<...
0x001a0070  4a00 0000 8805 0000 4203 0000 0000 0000  J.......B.......
0x001a0080  5b49 592d cc08 0000 3200 0000 0009 0000  [IY-....2.......
0x001a0090  fa02 0000 0000 0000 cdea ce32 fc0b 0000  ...........2....
0x001a00a0  4200 0000 400c 0000 3003 0000 0000 0000  B...@...0.......
0x001a00b0  c85f 5038 700f 0000 5e00 0000 d00f 0000  ._P8p...^.......

 Registers
  edi 0x00000000      esi 0x00000000      ebx 0x00341000      edx 0x00000000
  ecx 0x00000000      eax 0x004011b0      ebp 0x00000000      eip 0x77200cc0
  eflags 1I           esp 0x0019fff0

 RegisterRefs
  dr0 0x00000000  ebp
  dr1 0x00000000  ebp
  dr2 0x00000000  ebp
  dr3 0x00000000  ebp
  dr6 0x00000000  ebp
  dr7 0x00000000  ebp
  ctw 0x0000027f
  stw 0x00000000  ebp
  tag 0x0000ffff
  ero 0x00000000  ebp
  ers 0x00000000  ebp
  dao 0x00000000  ebp
  das 0x00000000  ebp
spare 0x00000000  ebp
```

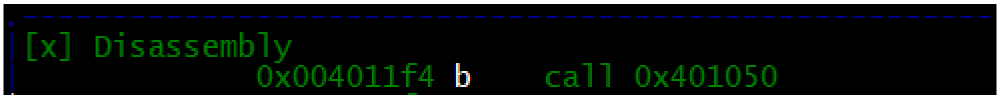
We can then use the command ‘s entry0’ to go to the main function of the binary. You can do this one of two ways. Either by quitting the visual mode using ‘qq’ and running the command in the normal view, or by running the command in the visual mode by using ‘:s entry0’. You can run any radare2 command in visual mode by prefacing it with ‘:’.

In entry0 we can see the program prompting us for a password.



```
0x004011dd        push str.G1v3_m3_t3h_fl4g:
0x004011e2        mov ecx, dword [0x403074]
0x004011e8        push ecx
0x004011e9        call dword [sym.imp.KERNEL32.dll_WriteFile]
0x004011ef        call 0x4010f0
0x004011f4        call 0x401050
```

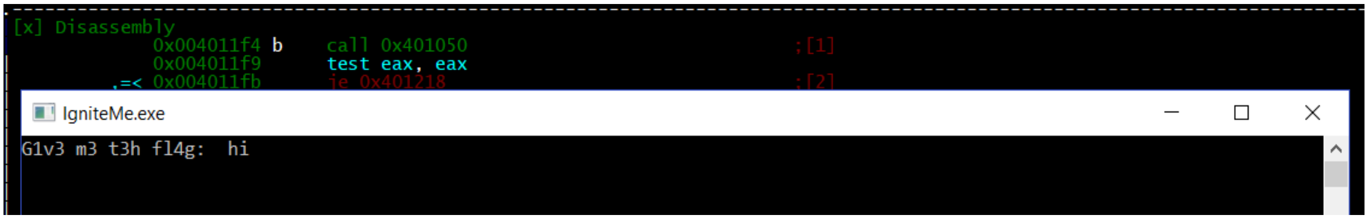
After it outputs the string using WriteFile, it then calls another function. Radare2 had a hiccup when analyzing this function as it should be titled ReadFile, which is how the program grabs our input. It then takes our input and runs it through the function at 0x401050. We can set a breakpoint here by going back to our 'V!' mode, scrolling until that line is at the top of the page and hitting F2.



```
[x] Disassembly
           0x004011f4 b    call 0x401050
```

Then we can run the program using the F9 key. Radare2 will automatically stop us when a blank command prompt comes up, so we need to go back into radare2 and hit F9 again. We will then need to input our string and hit ENTER, we will then stop at the breakpoint we just created.

Blank console from first F9

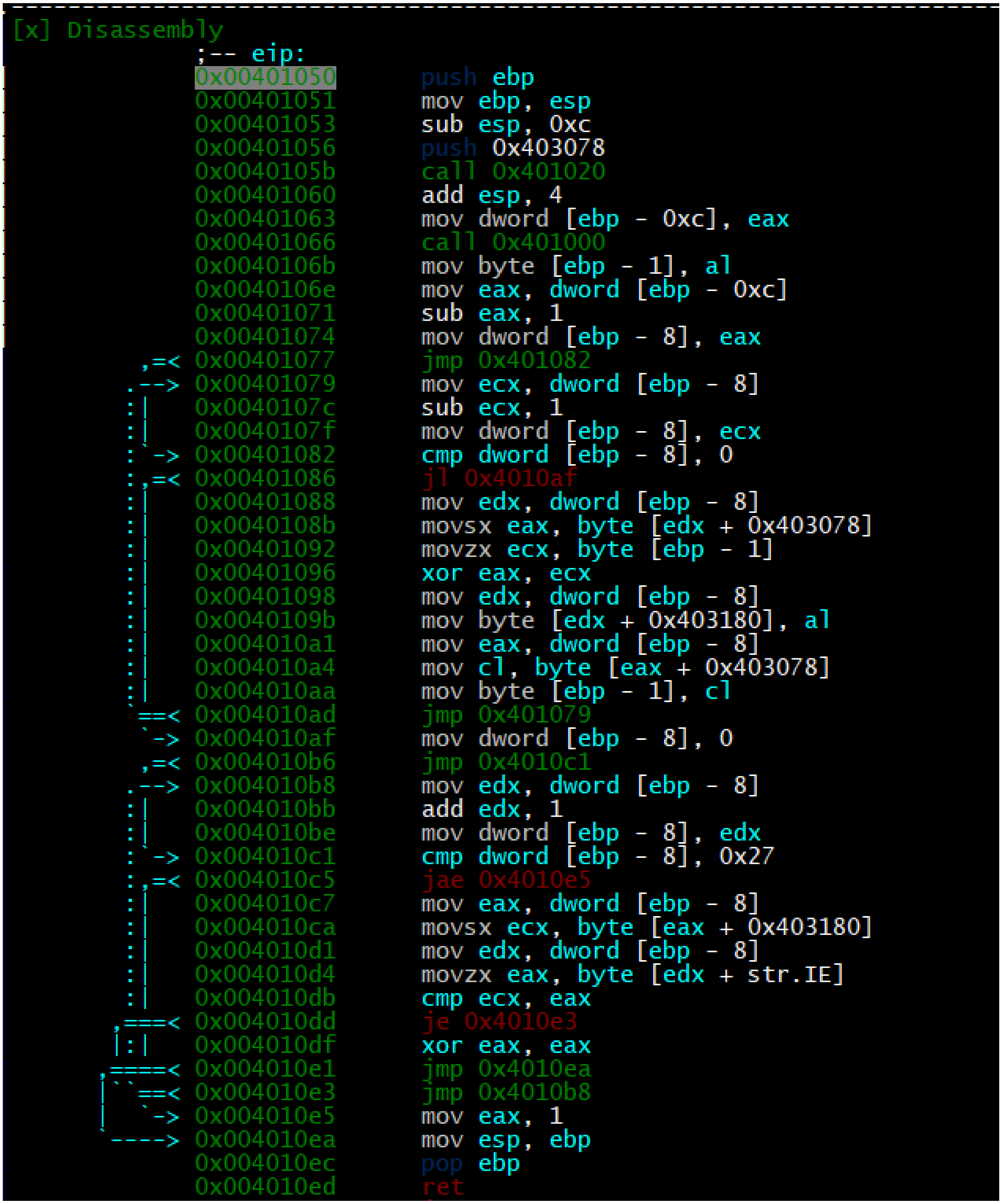


```
[x] Disassembly
           0x004011f4 b    call 0x401050                    ;[1]
           0x004011f9      test eax, eax
        ,=< 0x004011fb     je 0x401218                      ;[2]
```

```
G1v3 m3 t3h fl4g:  hi
```

After hitting F9 again and inputting our guess at the password

Now that we are at this function we can step into it using the F7 key. This will take us one instruction into the function and then stop.



```
[x] Disassembly
             ;-- eip:
             0x00401050      push ebp
             0x00401051      mov ebp, esp
             0x00401053      sub esp, 0xc
             0x00401056      push 0x403078
             0x0040105b      call 0x401020
             0x00401060      add esp, 4
             0x00401063      mov dword [ebp - 0xc], eax
             0x00401066      call 0x401000
             0x0040106b      mov byte [ebp - 1], al
             0x0040106e      mov eax, dword [ebp - 0xc]
             0x00401071      sub eax, 1
             0x00401074      mov dword [ebp - 8], eax
          ,=< 0x00401077      jmp 0x401082
         .--> 0x00401079      mov ecx, dword [ebp - 8]
         :|   0x0040107c      sub ecx, 1
         :|   0x0040107f      mov dword [ebp - 8], ecx
         :`-> 0x00401082      cmp dword [ebp - 8], 0
         :,=< 0x00401086      jl 0x4010af
         :|   0x00401088      mov edx, dword [ebp - 8]
         :|   0x0040108b      movsx eax, byte [edx + 0x403078]
         :|   0x00401092      movzx ecx, byte [ebp - 1]
         :|   0x00401096      xor eax, ecx
         :|   0x00401098      mov edx, dword [ebp - 8]
         :|   0x0040109b      mov byte [edx + 0x403180], al
         :|   0x004010a1      mov eax, dword [ebp - 8]
         :|   0x004010a4      mov cl, byte [eax + 0x403078]
         :|   0x004010aa      mov byte [ebp - 1], cl
         `==< 0x004010ad      jmp 0x401079
          `-> 0x004010af      mov dword [ebp - 8], 0
          ,=< 0x004010b6      jmp 0x4010c1
         .--> 0x004010b8      mov edx, dword [ebp - 8]
         :|   0x004010bb      add edx, 1
         :|   0x004010be      mov dword [ebp - 8], edx
         :`-> 0x004010c1      cmp dword [ebp - 8], 0x27
         :,=< 0x004010c5      jae 0x4010e5
         :|   0x004010c7      mov eax, dword [ebp - 8]
         :|   0x004010ca      movsx ecx, byte [eax + 0x403180]
         :|   0x004010d1      mov edx, dword [ebp - 8]
         :|   0x004010d4      movzx eax, byte [edx + str.IE]
         :|   0x004010db      cmp ecx, eax
        ,===< 0x004010dd      je 0x4010e3
        |:|   0x004010df      xor eax, eax
       ,====< 0x004010e1      jmp 0x4010ea
       |``==< 0x004010e3      jmp 0x4010b8
       |  `-> 0x004010e5      mov eax, 1
       `----> 0x004010ea      mov esp, ebp
             0x004010ec      pop ebp
             0x004010ed      ret
```

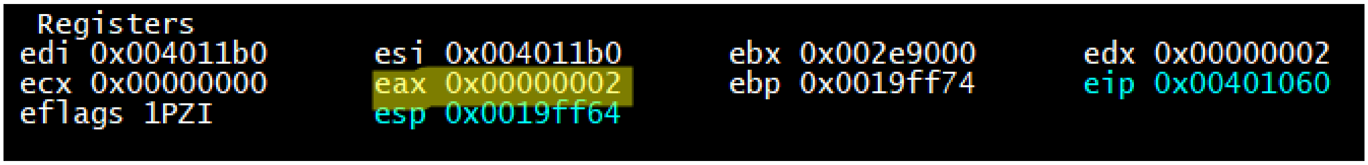
Output of the function we stepped into

Looking at this it looks like it is encrypting our string and then comparing it to str.IE. We can step through this function step by step to see exactly HOW it is encrypting our given string.

First I used the F7 key to single step through the application until it reached

```
call 0x401020
```

I was lazy and didn’t feel like single stepping through this function, so I used the F8 to step over the function. I then took a look at the right side of the window to see what eax is, since functions normally return their data in eax.

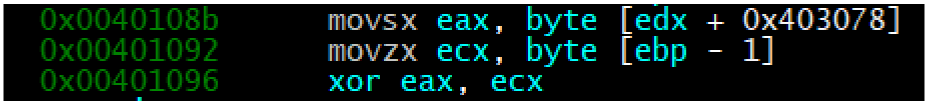


```
 Registers
edi 0x004011b0        esi 0x004011b0        ebx 0x002e9000        edx 0x00000002
ecx 0x00000000        eax 0x00000002        ebp 0x0019ff74        eip 0x00401060
eflags 1PZI           esp 0x0019ff64
```

Here we can see that eax is 2, which is the length of our string. So all that function did was check the length of our string. Let’s step a little more and see what that next function does.

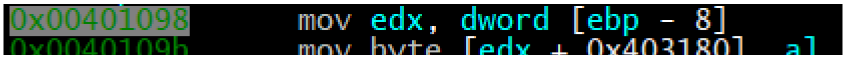
I stepped over the function 0x401000 and it returned the hex value 0x00700004 and moved al into [ebp-1]. Essentially this just puts the number 4 into [ebp-1] we’ll see why we do this later.

We then see that we move the length of our string [ebp-0xc] into eax and start a loop that goes through each character in the string. As we step a little further through this we notice that the last letter of our string is placed into eax and the value in [ebp-1] is placed into ecx. We then xor the two values together to start the process of encrypting our string.

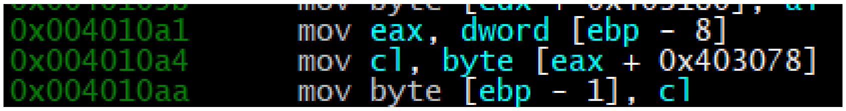


```
0x0040108b      movsx eax, byte [edx + 0x403078]
0x00401092      movzx ecx, byte [ebp - 1]
0x00401096      xor eax, ecx
```

We then place the last letter in our submitted plaintext string into [ebp-1] and start the loop again.



```
0x00401098      mov edx, dword [ebp - 8]
0x0040109b      mov byte [edx + 0x403180], al
```



```
0x004010a1      mov eax, dword [ebp - 8]
0x004010a4      mov cl, byte [eax + 0x403078]
0x004010aa      mov byte [ebp - 1], cl
```

So what it looks like we're doing is xoring each letter of the string by the previous letter. If there is no previous letter than we xor that value by 4.

So for our string 'hi' we xor 'i' by 4 and xor 'h' by 'i'. So our encrypted string becomes 0x1 0x6d. Looking later down the program we can see it compares this encrypted string to this string letter by letter.

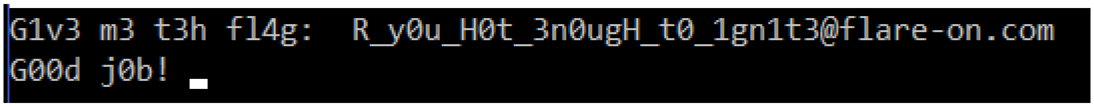
```
\r&IE*\x17xD+l]^E\x12/\x17+DonV\t_EGs&\n\r\x13\x17HB\x01@M\f\x02i
```

Some of these values are hexadecimal values instead of strings. This is radare2's way of parsing the data. Now that we know what is going on we don't need to debug the application anymore and can move to decrypting that string to find out what the flag is. The nice thing about xor is that we can use it to both encode and decode. So the way to decode this string is to xor the last character by 4, take the next value and xor it by the previous decoded value.

```
i^4 = m
0x02^m = o
\f^o = c
M^c = .
@^. = n
0x01^n = o
B^o = -
H^- = e
0x17^e = r
0x13^r = a
\r^a = l
\n^l = f
&^f = @
s^@ = 3
G^3 = t
E^t = 1
_^1 = n
\t^n = g
V^g = 1
n^1 = _
o^_ = 0
D^0 = t
```

```
+^t = _
0x17^_ = H
/^H = g
0x12^g = u
E^u = 0
^^0 = n
]^n = 3
l^3 = _
+^_ = t
D^t = 0
x^0 = H
0x17^H = _
*^_ = u
E^u = 0
I^0 = y
&^y = _
\r^_ = R
```

So the flag is R_y0u_H0t_3n0ugH_t0_1gn1t3@flare-on.com. If we put that in we see that we pass the challenge.



```
G1v3 m3 t3h fl4g:  R_y0u_H0t_3n0ugH_t0_1gn1t3@flare-on.com
G00d j0b!
```

This has been a very basic info using the Radare2 debugger on Windows. I personally prefer using x64dbg when I debug applications, but this was a fun learning experience. As always if I did something wrong or there is some way I can improve then please feel free to reach out and tell me. You can contact me at my LinkedIn or my Twitter.

If you like this article you can view more on my updated blog at https://goggleheadedhacker.com/1

Thanks for reading and happy reversing!

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