Exploitation and Reverse Engineering

Lecture 6 - ECS198F SQ26

Plan of the Day

Exploring Binaries

- How do programs interact with memory when executed?
- What does it mean to “exploit” a binary?

Program Exploitation

- What are various techniques of exploiting a program, and ways to protect a binary?
- What tools can we use to assist in the process?

Reverse Engineering

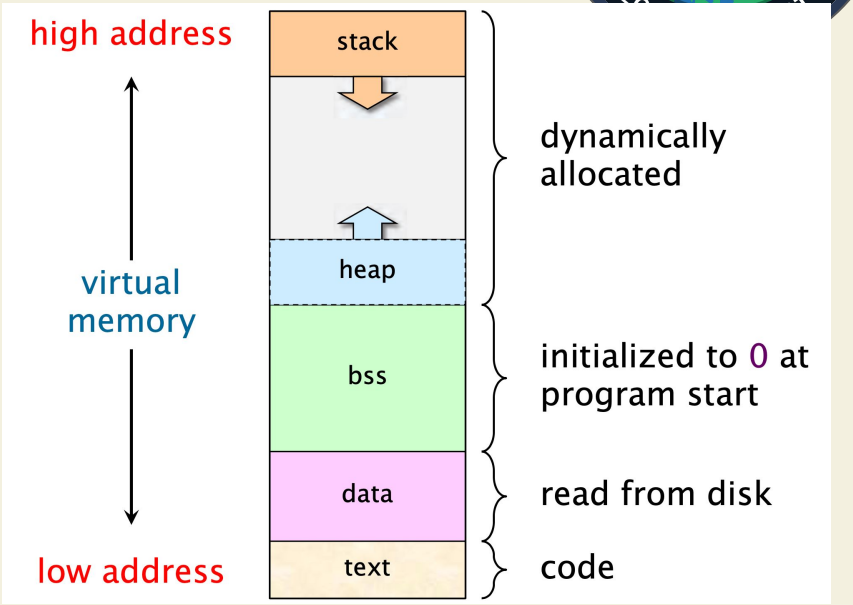
- How do you exploit a binary if you don’t know the source code?
- What reverse engineering tools exist, and how can we use them?

1. Program Exploitation Concepts

Quick Review of ECS 50

What happens when a program is run?

- Computer loads code and variables into memory, initializes some variables
- Allocates the stack and the heap
  - **Stack** - Stores information about the currently running function (local vars, args, etc.)
  - **Heap** - Dynamically allocated memory

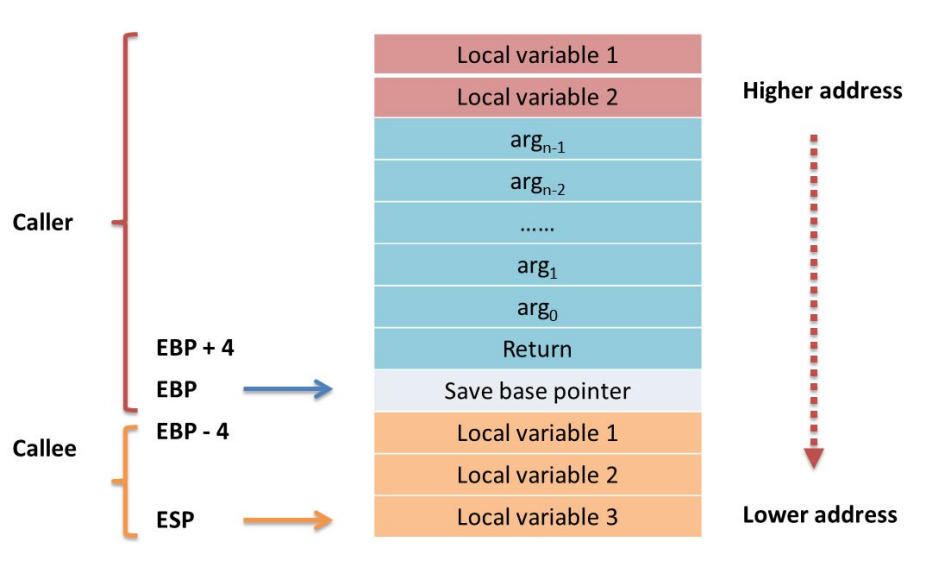


https://martinlwx.github.io/en/what-is-the-heap-and-stack/

Quick Review of ECS 50

What does the stack do and look like?

- Stores your local variables and arguments
- Stores information about the function that called the current one
  - Current function is everything between *ebp* and *esp*
  - Store location to jump to after execution is done!



https://nobelsharanyan.wordpress.com/wp-content/uploads/2015/05/function_stack1.png

So What Is Program Exploitation?

Basic Functions of a Computer

- Take Inputs
- Read/write from memory
- Perform operations
- Produce outputs

What can we do?

- Give a program funny inputs
- **Read/Alter a program's memory**
- **Change the control flow or run custom code!**
- Achieve some desired output!

relevant tiktok strikes again

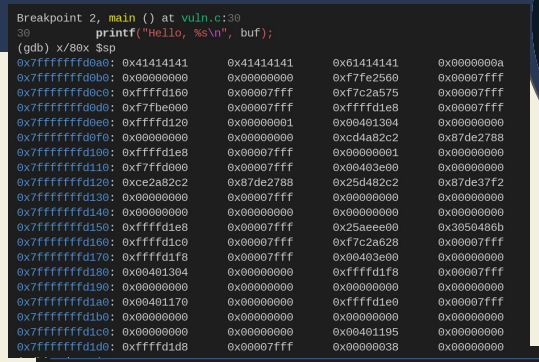
https://www.youtube.com/watch?v=Nz8ssH7LiB0

2. The Process of pwning

Tooling

Useful Tools in your Toolkit

- *gdb* - Yes, you can use a plain old debugger
  - *pwndbg* - Plugin for *gdb* that includes QoL features for exploit development
- *file, checksec* - Linux utilities that provide info about binaries
- *pwntools* - Python library that assists in exploit development



Demo #1: Buffer Overflows

https://play.picoctf.org/practice/challenge/438

https://play.picoctf.org/practice/challenge/439

Demo #2: Overflow the Stack

If stack variables are vulnerable to buffer overflow, what can we do with that control?

https://play.picoctf.org/practice/challenge/755

Protection Against Overflows?

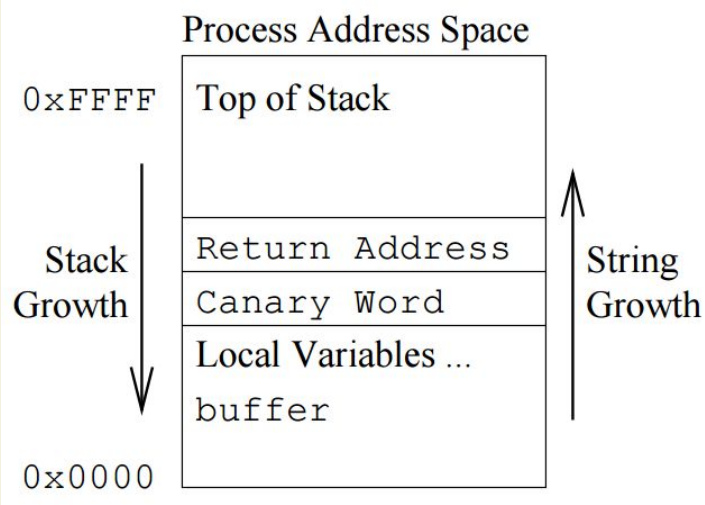
Possible Solution:

- Don’t use “unsafe functions…”
  - Could work!
- “Just don’t use C/C++”
  - I mean a lot of languages DO protect you (Python, Rust, etc.)
  - Not always about “exploitability”, the ability to make a program crash is just as important!
- Make the operating system protect you against some attacks!

Operating System Protections

Enter stack canary!

- Some random piece of data inserted at runtime to check if “stack smashing” is occuring
  - If it is, kill the program
- Can be turned off; or, if you have the right exploit, leaked
  - Use *checksec* to see if it’s enabled!



https://tianocore-docs.github.io/ATBB-Mitigate_Buffer_Overflow_in_UEFI/draft/media/image2.png

Format String Vulnerabilities


```c
// Assume some user input in a variable user_input

int main() {
    char user_input[50];

    printf(user_input);

    printf("%s", user_input);

    return 0;
}
```

Which one of these printf's is vulnerable, and what is not?

Format String Vulnerabilities

`printf(variable)` allows users to pass in arbitrary format strings to read!

- Enables “stack walking” by sending a format string saying you have a lot more variables to print! (%x, %p)
- Arbitrary writes with space padding chained with %n!

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// Assume some user input in a variable user_input

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}
```

Demo #3: Format String Vulns

https://play.picoctf.org/practice/challenge/434

Arbitrary Code Execution Techniques

- **Shellcode** - Inject assembly instructions into memory, and tell computer to run it
- **Return-Oriented Programming (ROP)** - Jump execution around existing code to chain together a program (avoids protections)

Protections Against ACE

- **PIE / ASLR** - Randomize memory addresses of programs AND segments to make execution less predictable
- **DEP** - Don't allow execution from certain memory segments (stack, etc.)

https://ctf101.org/binary-exploitation/return-oriented-programming/

3. Reverse Engineering

Ideas of Reverse Engineering

Objectives

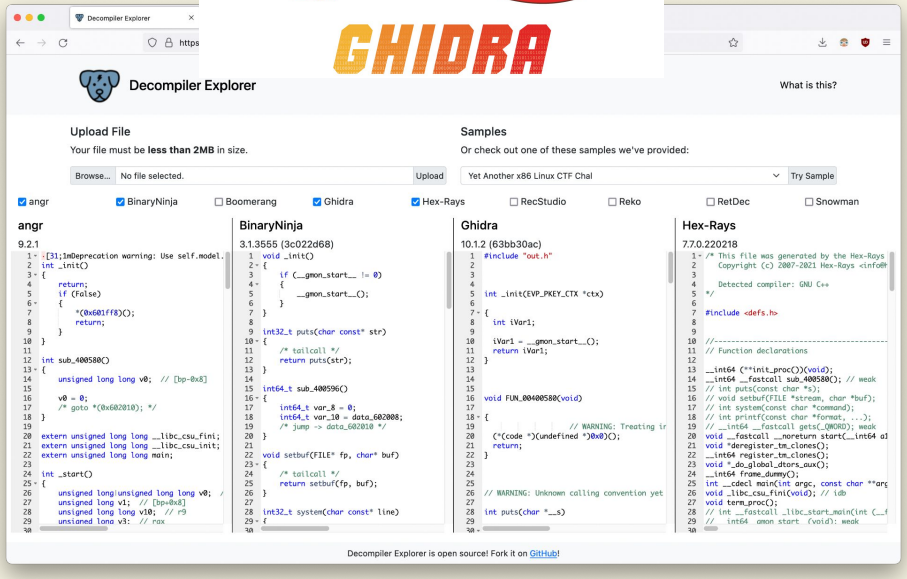
1) Understand how a program works (source code usually not provided)
2) Check it for anything of interest (vulnerabilities, functionality, etc.)

Challenges

- **You gotta figure out what all the variables and functions do**
    - If debug symbols / mapping not provided, you have to make sense of the noise
- Interpretation may vary! Some tools represent the same thing different ways!

Tooling

- **Decompiler** - Program that attempts to map assembly instructions back into code
    - Dogbolt (Decompiler Explorer), Ghidra, IDA/Binary Ninja
- **Disassembler** - Get the assembly instructions from the machine code



Last Demo

https://github.com/SunshineCTF/SunshineCTF-2025-Public/tree/main/i95/Jupiter