System Security - Attack and Defense for Binaries

CS 4390/5390, Spring 2026

Instructor: MD Armanuzzaman (***Arman***)

Getting to know ourselves

- Name
- Undergraduate
    - What excites you in CS/Cybersecurity/research direction?
- Graduate
    - What is your research direction?
    - Advisor?
- What do you expect to learn from this course?
    - High-level is fine
    - If you just found the term hacking exciting, it's also fine

Logistics

- Class attendance
- Keep a notebook
- Always bring your laptop
- We will hack in a class CTF platform
- During the lectures feel free to interrupt and ask questions
- Class website : slides will be posted here
- Homework submissions on blackboard

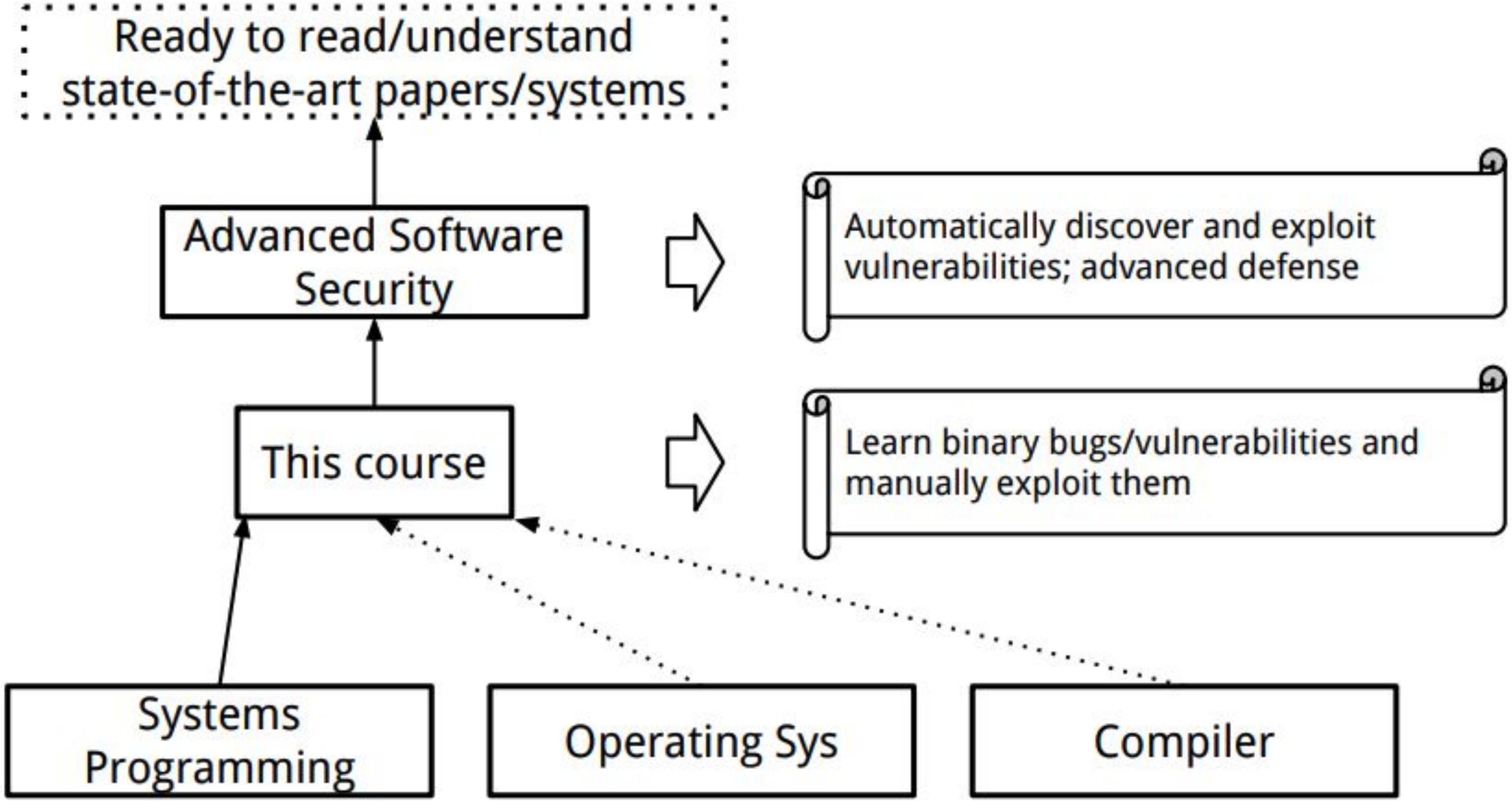
Instructor

- Dr. MD Armanuzzaman, Assistant Professor at UTEP
  - Just call me **Arman**
- Email: marmanuzzaman@utep.edu
- Website: https://tomal-kuet.github.io/armanuzzaman/
- Office hours on TR: 1.30PM - 3.00PM
  - In person at CCSB: 3.1008 or Teams (course website)
- Research area: Systems and Software Security
  - Embedded and IoT systems, Cloud systems, FPGAs, Fuzzing, etc.
- Looking for team members:
  - I am currently looking BS/MS/PhD students to join my research team.

Course Goals

- To provide you with good understanding of the **theories, principles, techniques** and **tools** used for binary software and system hacking and defense.
- By software and system, I mean native software, binary, most likely developed in C/C++. The security of web software, Java, Python are out of the scope.
- You will study, in-depth, binary reverse engineering, vulnerability classes, vulnerability analysis, exploit/shellcode development, defensive solutions, etc., to understand how to crack and protect **native** software.
- You will get your hands dirty.

If you want to be a systems/software security guy …



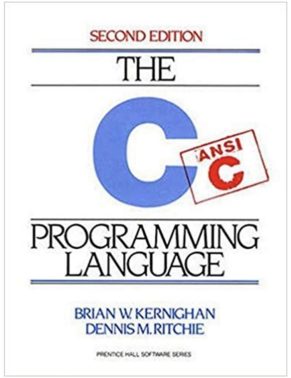
Ready to read/understand state-of-the-art papers/systems
Advanced Software Security
Automatically discover and exploit vulnerabilities; advanced defense
This course
Learn binary bugs/vulnerabilities and manually exploit them
Systems Programming
Operating Sys
Compiler

First week’s Agenda

- Class overview and logistics
- Background knowledge
    - Compiler, linker, loader
    - x86 and x86-64 architectures and ISA
    - Linux fundamentals
        - Linux file permissions
        - Set-UID programs
        - Memory map of a Linux process
        - System calls
        - Environment and Shell variables
    - Basic reverse engineering

Prerequisites

- The real prerequisite:
  - The C Programming Language
- Classes that will help you understand this class:
  - Systems Programming
  - Operating Systems
- Other skills:
  - Reverse engineering (Using objdump, IDA Pro, Ghidra, etc.)
  - Debugging (GDB, pwngdb)
- Google, reading, self-learning, getting hands dirty



Topics

Binary attack and defense using x86 and x86-64 as examples.

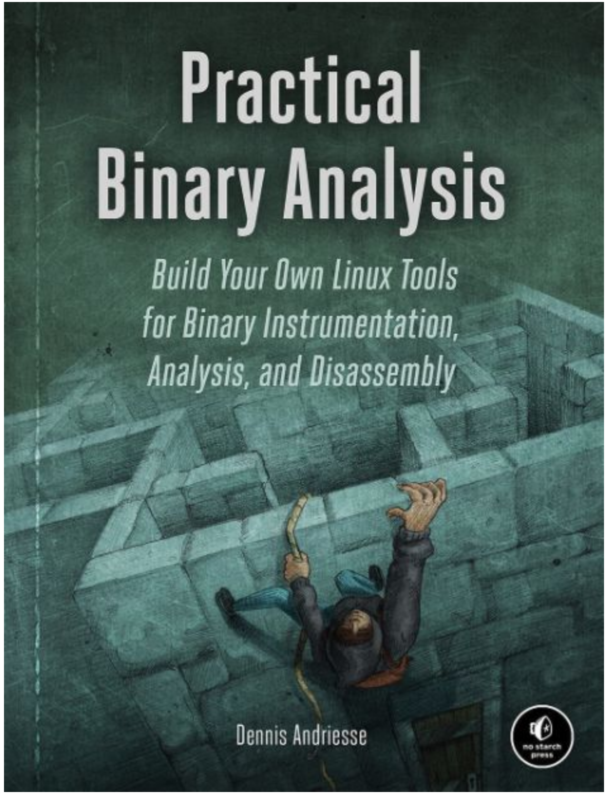
Discover **vulnerabilities**. Develop **exploits**. Memory corruption attacks.

1. Stack-based buffer overflow
2. Defenses against stack-based buffer overflow
3. Shellcode development
4. Format string vulnerabilities
5. Heap-based buffer overflow
6. Integer overflow
7. Return-oriented programming
8. ....

Related Books and Papers

- SoK: Eternal War in Memory. IEEE S&P 2013
- SoK: (State of) The Art of War: Offensive Techniques in Binary Analysis. IEEE S&P 2016
- SoK: Shining Light on Shadow Stacks. IEEE S&P 2019

Practical Binary Analysis: Build Your Own Linux Tools for Binary Instrumentation, Analysis, and Disassembly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Related Books and Papers

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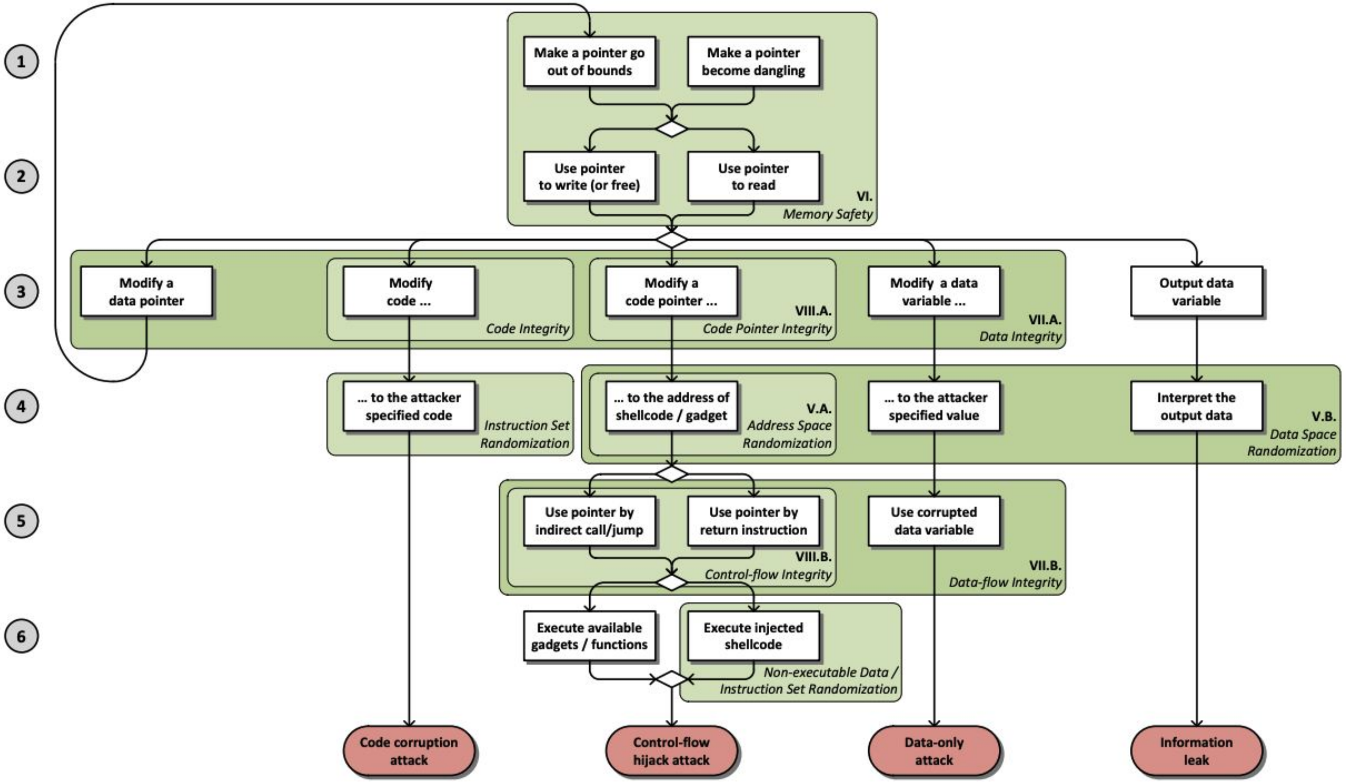
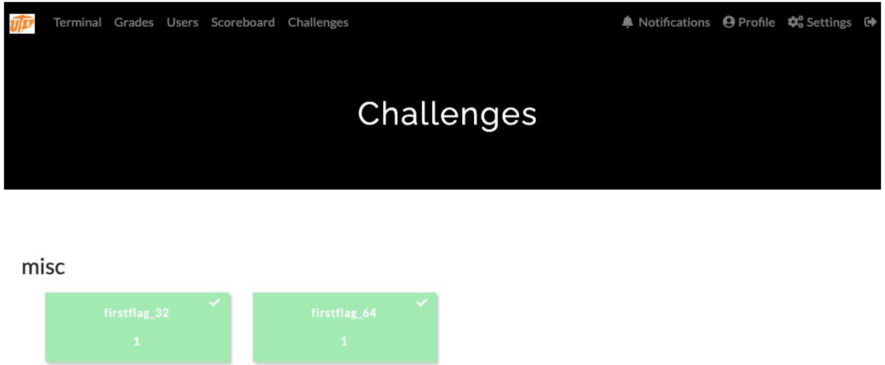

1
2
3
4
5
6
Make a pointer go out of bounds
Make a pointer become dangling
Use pointer to write (or free)
Use pointer to read
VI.
Memory Safety
Modify a data pointer
Modify code ...
Code Integrity
Modify a code pointer ...
VIII.A.
Code Pointer Integrity
Modify a data variable ...
VII.A.
Data Integrity
Output data variable
... to the attacker specified code
Instruction Set Randomization
... to the address of shellcode / gadget
V.A.
Address Space Randomization
... to the attacker specified value
Interpret the output data
V.B.
Data Space Randomization
Use pointer by indirect call/jump
Use pointer by return instruction
VIII.B.
Control-flow Integrity
Use corrupted data variable
VII.B.
Data-flow Integrity
Execute available gadgets / functions
Execute injected shellcode
Non-executable Data / Instruction Set Randomization
Code corruption attack
Control-flow hijack attack
Data-only attack
Information leak

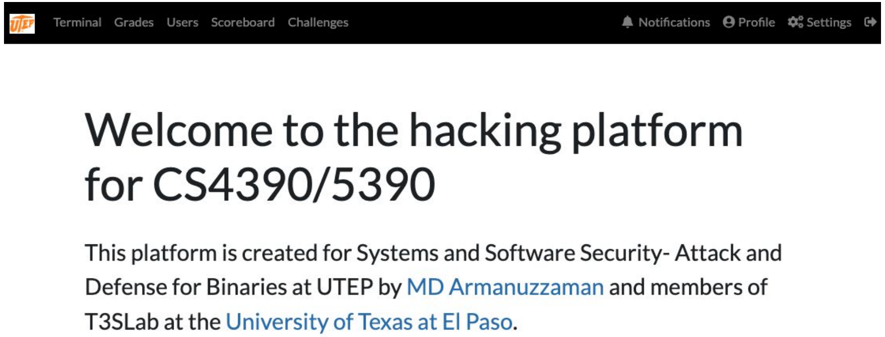
The Hacking Environment

http://yeast.utep.edu:2223/

Only UTEP students can access this website. If you are off-campus, you need VPN to connect to UTEP network to access

Register and account with your **UTEP username and email address**, so I know who you are





Welcome to the hacking platform for CS4390/5390

This platform is created for Systems and Software Security- Attack and Defense for Binaries at UTEP by MD Armanuzzaman and members of T3SLab at the University of Texas at El Paso.

The Hacking Environment

- Intel x86
- x86-64, a.k.a amd64
- *ARM Cortex-A, Cortex-M*
- Linux (Ubuntu)

- Pwngdb
- Pwntools
- GDB peda
- NSA Ghidra
- Binary Ninja

Homework

- Reading: book chapter, whitepaper, paper, blog, etc.
- Hands-on: hacking, debugging, etc.
- Submit before a class on blackboard. We may discuss homework at the beginning of each class.

- 30% penalty if you submit within 10 mins after class starts. 0 points after 10 mins.
- 0 points for homework if plagiarising is found. No exceptions.

Disability Access Services

If you need DAS, please inform me in the first two weeks.

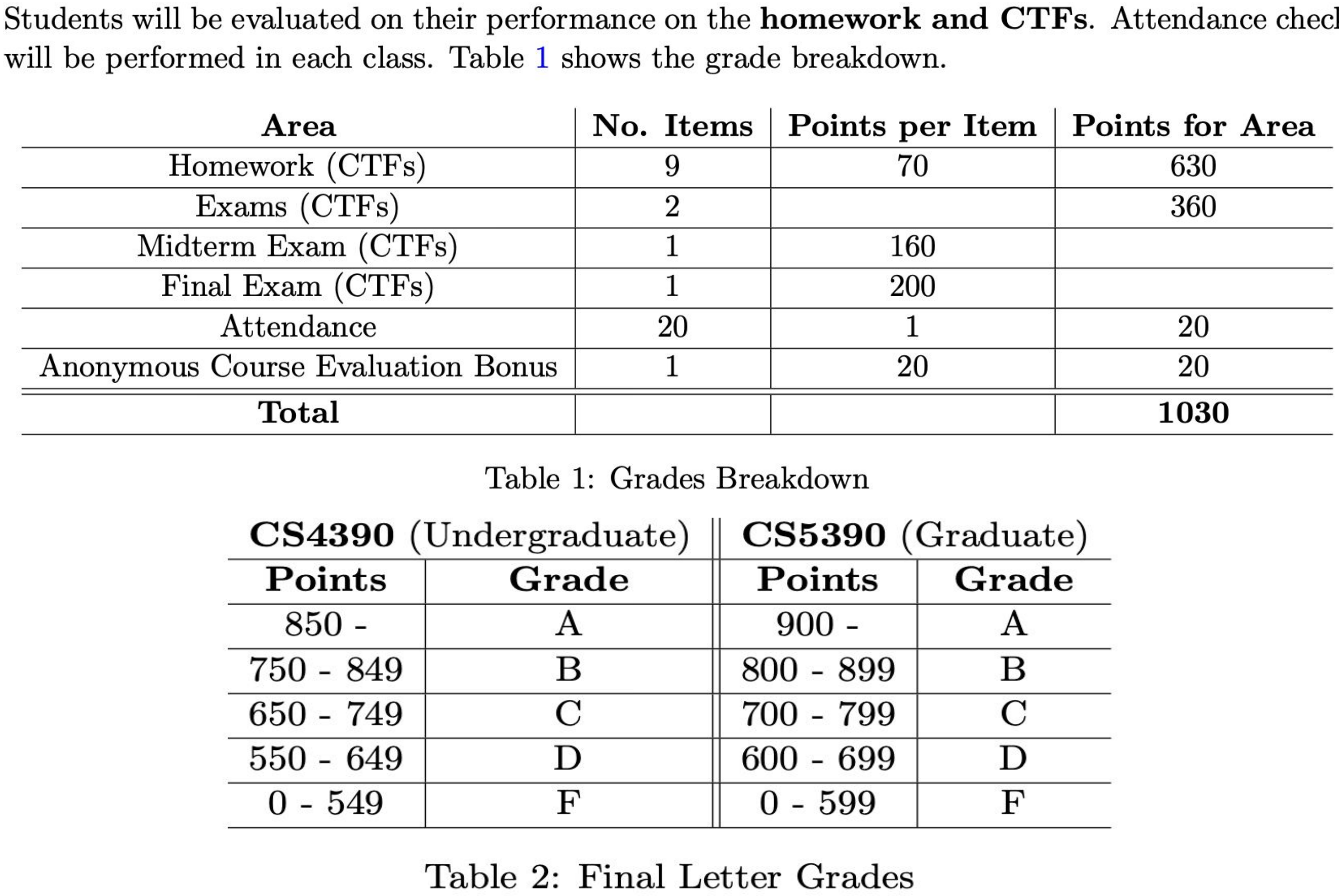
Hacking Assignment Rules

- For each hacking assignment, you will submit your exploit, a simple write-up, and screenshots to show it works
    - Simple write-up:
        - Briefly describe how you solve the challenge
        - Mention who you worked with if any in the write-up
- Discussion is encouraged. But, you cannot share your code, exploits, write-ups to your classmates or post them online

Exams, a.k.a, Capture-the-Flag (CTF) Hacking

- Midterm CTF: 3 hours and 20 minutes
- Final CTF: 3 hours and 20 minutes

Grades



Students will be evaluated on their performance on the **homework and CTFs**. Attendance checl will be performed in each class. Table 1 shows the grade breakdown.

Area	**No. Items**	**Points per Item**	**Points for Area**
Homework (CTFs)	9	70	630
Exams (CTFs)	2		360
Midterm Exam (CTFs)	1	160	
Final Exam (CTFs)	1	200	
Attendance	20	1	20
Anonymous Course Evaluation Bonus	1	20	20
Total			**1030**

Table 1: Grades Breakdown

CS4390 (Undergraduate)		**CS5390** (Graduate)	
Points	**Grade**	**Points**	**Grade**
850 -	A	900 -	A
750 - 849	B	800 - 899	B
650 - 749	C	700 - 799	C
550 - 649	D	600 - 699	D
0 - 549	F	0 - 599	F

Table 2: Final Letter Grades

Academic Integrity

Your first assignment is to to read the UTEP academic integrity policies

Here are examples for your consideration

- you work on your laptop at a library with friends and step away from your computer without locking it
- you look at your neighbors' screen/papers during an exam, but don't copy their answers
- you take a piece of code from some website and give a link to the website at the end of the homework
- you work on a homework problem with friends, type the solution at home, but it's exactly the same as that of your friends

Academic Integrity

- Discussion is encourage. But, you cannot share your code, exploits to your classmates or post them online.
- The university, college, and department policies against academic dishonesty will be strictly enforced. To understand your responsibilities as a student read: UTEP Student Code of Conduct.
- Plagiarism or any form of cheating in homework, assignments, labs, or exams is subject to serious academic penalty.
- Any violation of the academic integrity policy will result in a 0 on the homework, lab or assignment, and even an F or >F< on the final grade. And, the violation will be reported to the Dean’s office.

ChatGPT/LLM Policy

- ChatGPT/LLM is forbidden in the midterm and final CTFs

Ethical Hacking

- Do not attempt to violate the law.
- If you discover real-world vulnerabilities using the knowledge you learn from this class, report the vulnerabilities responsibly. Companies may reward you for that.

Thank you