CS 453 / 698
Software and Systems Security

Module 1
Introduction to Software and Systems Security

Fall 2024

Instructors

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CS 453 / 698

- This is the **third** offering of this course
- The pilot edition was offered in Spring'23
- This course expands on a few topics taught in CS458/658 (Computer Security and Privacy)
- Expands on the Security Aspect
- The course includes (pilot) experimental topics

- We seek your feedback on the course content, delivery and topics covered

CS 453 / 698 (Prerequisites)

- CS 350 (Operating Systems)
- Familiarity with C

Instructor Office Hours

- Weekly Office hours: Thursdays 2:00 – 3:00 pm virtual

  Link: https://bbb.crysp.org/rooms/men-slj-j7n-0lq/join

  Access code: 1xszia

- In-person office hours by appointment only
- Instructor office hours are meant to answer questions related to module content, course policies, syllabus matters, and special situations

Teaching Assistants

- Andre Kassis
- Haseeb-Ur-Rehman Faheem
- Ruizhe Wang

Office hours on Fridays 1:00pm to 2:00pm;

Link: https://bbb.crysp.org/rooms/i01-wb5-pvq-hc9/join

Access code: 6gx9wq

Course Mechanics

- Campus and CS VPNs: remote working
- student.cs account: code submission
  - If you don't have a student.cs account for some reason, ask cscfhelp@uwaterloo.ca for help
- LEARN: assignment and grade distribution

Communication Channel

- Important course announcements will be made on Piazza.
  - Please keep up with the information there.
- Use discussion forums in Piazza for all communication
  - Use a **private** question for questions not of general interest
- Use email only as a last resort and then it must be from your uwaterloo.ca email address

- Some communication might be sent to your uWaterloo email address
  - Check your uWaterloo email account regularly or have email forwarded to your regular account

Course Mechanics

- Piazza: Q&A, general discussions
- Logistics, office hours links, assignment due dates, etc
- Module Discussions – the place to ask questions about that module's content
- Assignment Discussions – the place to ask questions about assignments
- …

Course Mechanics

- Course website: syllabus, slides, public materials

https://cs.uwaterloo.ca/~m285xu/courses/cs453-f24/

Course Syllabus

https://cs.uwaterloo.ca/~m285xu/courses/cs453-f24/syllabus/

- You are expected to be familiar with the contents of the course syllabus
- If you haven't read it, read it after this lecture

Course Website

- https://cs.uwaterloo.ca/~m285xu/courses/cs453-f24/modules/

- Contains the lecture slides
- A draft of the lecture slides for each module will be made available before the module begins.

- The final version of the lecture slides will be made available after the module is completed

Course Calendar

- Course schedule:

https://cs.uwaterloo.ca/~m285xu/courses/cs453-f24/schedule/

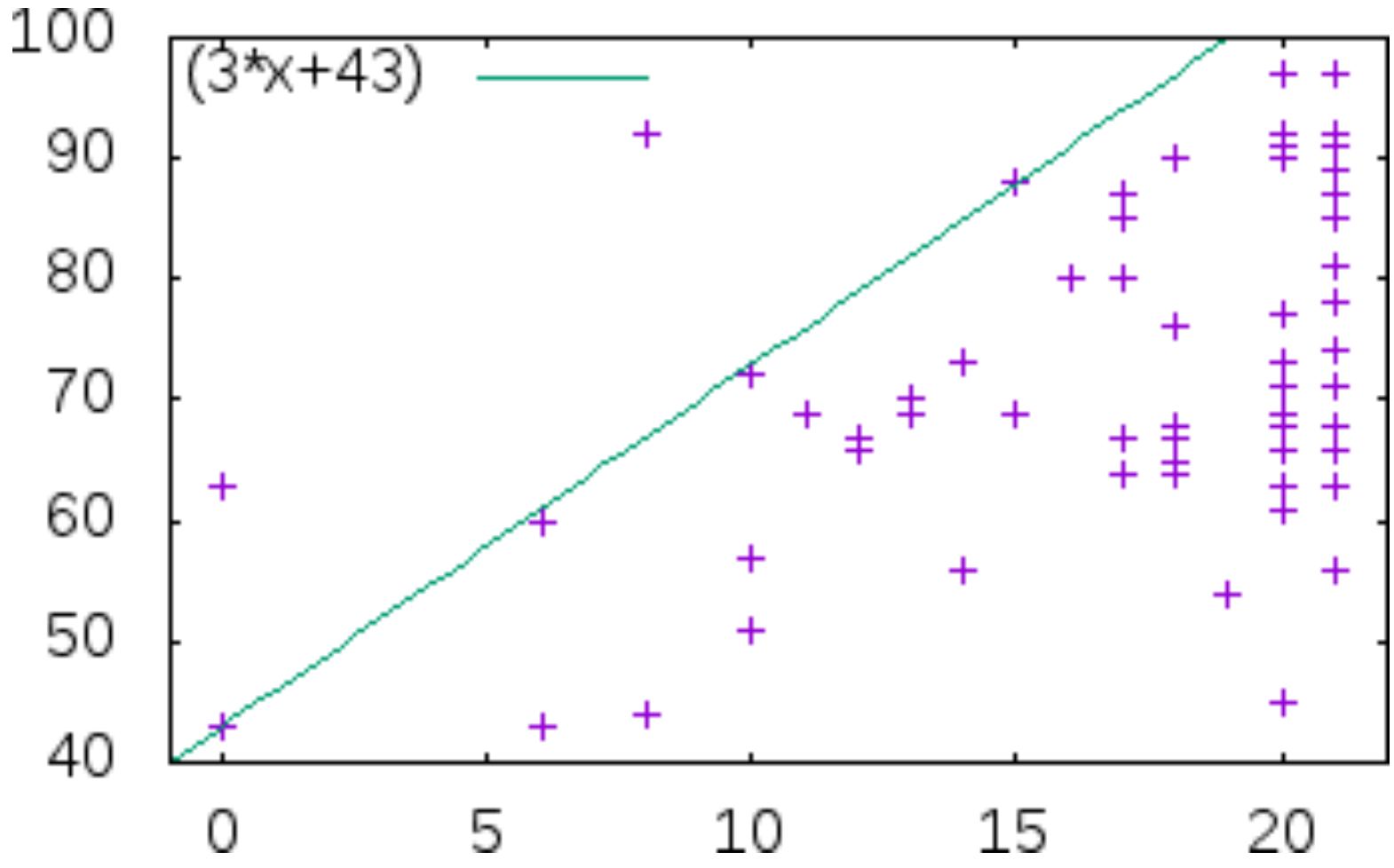
- Assignment (and milestones, if any) due dates
- Research project dates (applies to CS698 only)

- Make sure to check regularly

Per-student information

- Per-student information will be distributed using LEARN:
  - Link to be provided in Assignment Handouts
- Assignment marks and comments
- Details regarding Login accounts for assignment machines will be provided in Assignment Handouts

Attend the Lectures!



Grading Scheme

- 4 Assignments (each worth 25%)
  - Might contain either written and programming portions, or both
  - Work alone
- No Final Assessment
- For CS698: an additional research project is required
  - See syllabus for more details
  - Grading scheme = 4 x 20% (Assignments) + 20% (Research Project)
- See syllabus for late and reappraisal policies, academic integrity policy, and other details

Assignments

- Assignments will be due at the end of the day (i.e., 11:59pm) Waterloo time.
  - CS698: Same applies to the research project
  - Assignments should be submitted electronically per the instructions provided in the handouts
  - See CSCF submit page for more details.
- Important Notes:
  - Only assignments submitted with the official submission system will be accepted

Late Policy

- No assignments will be accepted after the due date (unless you have a Verification of Illness Form and a doctor's note)
- Recommendation: Submit early and submit often!
- You must notify your instructor well before the due date (at least 1 week) of any severe, long-lasting problem preventing you from completing an assignment on time
- No lates are accepted for the CS698 research project

Re-appraisal

- You can request a re-appraisal for graded assignments
- You need to provide a clear justification of why you think the assignment should be regraded
- We will allow re-appraisal requests within one week of grade release
- Submit requests on the course's Piazza

Plagiarism and Academic Offenses

- We take academic offenses very seriously
  - Even (especially?) in fourth year
- Nice explanation of plagiarism online
  - https://uwaterloo.ca/math/academic-matters/academic-integrity
- Read this and understand it
  - Ignorance is no excuse!
  - Questions should be brought to instructor
- Plagiarism applies to both text and code.
- You are free (even encouraged) to exchange ideas, but no sharing code or text.
- We may run submissions through MOSS to detect code similarity

Plagiarism (2)

- Common mistakes
  - Excess collaboration with other students
    - Share ideas, but no design or code!
  - Using solutions from other sources
  - Asking public questions containing (partial) solutions
  - Posting (partial) solutions to websites (e.g., github)
- Possible penalties
  - First offense (for assignments; exams are harsher)
    - 0% for that assignment, -5% on final grade
  - Second offense
    - More severe penalties, including suspension
- Penalties for graduate students are more severe
- More information linked to from course syllabus

A Note on Security

- In this course, you will be exposed to information about security problems and vulnerabilities with Software and Systems.
- To be clear, you are not to use this or any other similar information to test the security of, break into, compromise, or otherwise attack, any software or system without the express consent of the owner
- In particular, you will comply with all applicable laws and University policies.
- See syllabus for more details.

Recommended Textbooks

- **Computer Security and the Internet: Tools and Jewels from Malware to Bitcoin (2nd Edition)**, Paul van Oorschot, Springer, 2021.
- **Security in Computing**, 5th edition, Charles P. Pfleeger, Shari Lawrence Pfleeger, Jonathan Margulies, Prentice-Hall, 2015.

- Digital copies are available via the library website (linked from Course Syllabus)
- You are expected to know all the material presented in class, even if it's not in the textbooks.

Other readings

- From time to time, there will be additional assigned readings

- Links will be provided in the course website https://cs.uwaterloo.ca/~m285xu/courses/cs453-f24/modules/
- There will be both mandatory and optional readings

- You must read the mandatory ones before the class in which we will discuss them.
    - There is such a reading for the next lecture

Course Modules

1) Introduction to Software and Systems Security
2) Program Security
3) Operating System Security
4) Mobile Security
5) Common Bugs and Vulnerabilities
6) Bug Finding Tools and Practices
7) Defenses against Common Vulnerabilities
8) Hardware Security
9) Non-Technical Aspects in Security

Module outline

1. What is our goal in this course?
2. What is security?
3. How is it different from privacy?
4. Who are the adversaries?
5. Assets, vulnerabilities, threats, attacks, and defences
6. Methods of defence

What is our goal in this course?

- Our primary goal is to be able to identify security issues in various aspects of modern computing environments including:
  - Programs
  - Operating systems
  - Mobile systems
- Second, deploy state-of-the-art detection and defence mechanisms
  - To be able to use this ability to design systems that are more protective of security.

What is security?

- In the context of computers, security generally means three things:
  - **C**onfidentiality
    - Access to systems or data is limited to authorized parties
  - **I**ntegrity
    - When you receive data, you get the “right” data
  - **A**vailability
    - The system or data is there when you want it
- A computing system is said to be secure if it has all three properties
  - Well, usually

Security and reliability

- Security has a lot to do with “reliability”
- A secure system is one you can rely on to (for example):
  1. Keep your personal data confidential
  2. Allow only authorized access or modifications to resources
  3. Ensure that any produced results are correct
  4. Give you correct and meaningful results whenever you want them

Security vs. privacy

- Sometimes people place security and privacy as if they're opposing forces.
- Are they really? Do we have to give up one to get the other?

How is Privacy different from Security?

- There are many definitions of privacy
- A useful one: "informational self-determination"
  - This means that you get to control information about you
  - "Control" means many things:
    - Who gets to see it
    - Who gets to use it
    - What they can use it for
    - Who they can give it to
    - etc.

Example: PIPEDA

- PIPEDA (Personal Information Protection and Electronic Documents Act) is Canada's private-sector privacy legislation
- Lists ten Fair Information Principles companies need to abide by:
  1. Identify the purpose of data collection
  2. Obtain consent
  3. Limit collection
  4. Limit use, disclosure and retention
  5. Use appropriate safeguards
  6. Give individuals access
  7. Be accurate
  8. Be open
  9. Be accountable
  10. Provide recourse

(Read more: https://www.priv.gc.ca/leg_c/p_principle_e.asp)

Consumer Privacy Protection Act

- Forthcoming legislation to regulate private sector use of personal information.
- Modernizing protection: meaningful consent, right to erasure, etc.
- Stronger provisions for enforcement.
- Private right of action.

Who are the adversaries?

- Who's trying to mess with us?
- Various groups:
  - Murphy Amateurs
  - "Script kiddies"
  - Crackers or Hackers
  - Organised crime
  - Government "cyberwarriors"
  - Terrorists
  -
- Which of these is the most serious threat today?

Some terminology

- Assets
  - Things we might want to protect, such as:
    - Hardware
    - Software
    - Data
- Vulnerabilities
  - Weaknesses in a system that may be able to be exploited in order to cause loss or harm
  - e.g., a file server that doesn't authenticate its users
  - e.g., an API that allows accessing gps coordinates without authenticating apps

Some terminology

- Threats
  - A loss or harm that might befall a system
  - e.g., users' personal files may be revealed to the public

  - There are four major categories of threats:
    1. Interception
    2. Interruption
    3. Modification
    4. Fabrication

  - When designing a system, we need to state the threat model
    - Set of threats we are undertaking to defend against
    - Whom do we want to prevent from doing what?

Some terminology

- Attack
  - An action which exploits a vulnerability to execute a threat
  - e.g., telling the file server you are a different user in an attempt to read or modify their files
- Control/Defence
  - Removing or reducing a vulnerability
  - You control a vulnerability to prevent an attack and defend against a threat.
  - How would you control the file server vulnerability?
  - Our goal: control vulnerabilities

Methods of defence

- How can we defend against a threat?
  - Prevent it: prevent the attack
  - Deter it: make the attack harder or more expensive
  - Deflect it: make yourself less attractive to attacker
  - Detect it: notice that attack is occurring (or has occurred)
  - Recover from it: mitigate the effects of the attack
- Often, we'll want to do many things to defend against the same threat
  - "Defence in depth"
- How to defend against the following threat? your car may get stolen

Example of defence

- Threat: your car may get stolen
- How to defend?
  - Prevent: Immobilizer? Is it possible to absolutely prevent?
  - Deter: Store your car in a secure parking facility
  - Deflect: Have sticker mentioning car alarm, keep valuables out of sight
  - Detect: Car alarms,
  - Recover: Insurance

How secure should we make it?

- Principle of Easiest Penetration
  - "A system is only as strong as its weakest link"
  - The attacker will go after whatever part of the system is easiest for them, not most convenient for you.
  - In order to build secure systems, we need to learn how to think like an attacker!
  - How would you get private information from the US Social Security Administration database?

- Principle of Adequate Protection
  - "Security is economics"
  - Don't spend $100,000 to protect a system that can only cause $1,000 in damage

Weakest link

Defend like an attacker… too

Captured from Google Map Street View

Defence of computer systems

- Remember we may want to protect any of our assets
  - Hardware, software, data
- Many ways to do this
  - Cryptography
  - Software Controls
  - Hardware Controls
  - Physical Controls
  - Policies and Procedures

Defence of computer systems

- Cryptography
  - Protecting data by making it unreadable to an attacker
  - Authenticating users with digital signatures
  - Authenticating transactions with cryptographic protocols
  - Ensuring the integrity of stored data
  - Aid customers' privacy by having their personal information automatically become unreadable after a certain length of time

Defence of computer systems

- Software controls
  - Passwords and other forms of access control
  - Operating systems separate users' actions from each other
  - Virus scanners watch for some kinds of malware
  - Development controls enforce quality measures on the original source code
  - Personal firewalls that run on your desktop

Defence of computer systems

- Hardware controls
  - Not usually protection of the hardware itself, but rather using separate hardware to protect the system as a whole
  - Fingerprint readers
  - Smart tokens
  - Firewalls, intrusion detection systems
  - Trusted Execution Environments (TEEs)

Defence of computer systems

- Physical controls
  - Protection of the hardware itself, as well as physical access to the console, storage media, etc.
  - Locks
  - Guards
  - Off-site backups
  - Don’t put your data centre on a fault line in California
  - Don’t put your nuclear power plant in a tsunami zone

Defence of computer systems

- Policies and procedures
  - Non-technical means can be used to protect against some classes of attack
  - If an employee connects their own Wi-Fi access point to the internal company network, that can accidentally open the network to outside attack
    - So don't allow the employee to do that!
  - Rules about choosing passwords
  - Training in best security practices

Recap

- What is our goal in this course?
  - Identify security and privacy issues
  - Design systems that are more protective of security and privacy
- What is security?
  - Confidentiality, Integrity, Availability
- What is privacy?
  - Informational self-determination

Recap

- Who are the adversaries?
  - Learn to think like an attacker
- Assets, vulnerabilities, threats, attacks and controls
  - You control a vulnerability to prevent an attack and block a threat
- Methods of defence
  - Cryptography, software controls, hardware controls, physical controls, policies and procedures