Orientation

- This course is **Secure Programming**.
- More accurately: it is about **Software Security**.
- Aimed at Informatics **MSc and 4th/5th year**
- Primarily: those anticipating a career in software
  - **programming**: architects, developers, testers, ...
  - **security**: pentesters, malware/reverse engineers
  - **researchers**: verification, compilers, languages, ...
- It is taught by **David Aspinall**.

Public home page:
[http://www.inf.ed.ac.uk/teaching/courses/sp](http://www.inf.ed.ac.uk/teaching/courses/sp)

The Learn page has links to the lecture recordings (UoE only).

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Ubiquitous software is broken (2014)

Ubiquitous hardware is flawed (2018)

Old systems break operations (2017)

Attacks can cause physical damage (2014)
Why does this happen?

Ostensibly, many security failures are due to software vulnerabilities. Are they inevitable?

Many surrounding questions. Can we:

► find vulnerabilities (before attacks)?
► detect exploits in-the-wild?
► repair vulnerabilities (routinely/automatically)?
► program better to avoid vulnerabilities?
► measure risk associated with software?
► design or verify to prevent them?
► develop new technology to help the above?

Questions beyond the technical, too. Can we:

► insure against cyber incidents?
► regulate for better security?

What is this course about?

Building software that’s more secure

► finding flaws in existing software
► avoiding flaws in new software (design and code)
► techniques, tools and understanding to do this

The infrastructure around secure software:

► language, libraries, run-time; other programs
► data storage, distribution, protocols and APIs
► development and deployment methods

And first of all, setting policies for security

► what should be protected
► who/what is trusted
► risk assessment: cost of defences.

Target audience

► Aimed at MSc, 4th/5th year UGs
► Have passed Computer Security or similar
► Basic notions, crypto, protocols

► Programming practice
► should be confident in programming
► necessarily will use a range of languages
► … including assembler, C, Java
► but don’t have be “master hacker”
► grounded in software engineering

► Programming theory
► interest in PL concepts and design
► knowledge of compilers useful
► also software engineering, esp, testing
► theory courses helpful, semantics
### Why should you take this course?

**Want to work in the cyber security industry?**
- security appraisal, system and code reviewing
- pen-testing, ethical hacking
- malware analysis, reverse engineering
- operations and response (SOCs)
- cyber defence, attack, espionage
- innovation: found a cyber start-up

Want to work in security research?
- academic (conceptual advances, fixing, breaking)
- commercial (breaking, fixing, defending)

(Hopefully): you think it's **fun and interesting**!

### Why should you *not* take this course?

- None of the previous points apply
- You don’t have the right background (see next slide)
- Perhaps: you know (almost all of) it already

Warning: We try to keep the course up-to-date so it is sometimes “rough at the edges”.

### Expected background

Please see Guide to Background Needed on course homepage.

1. Security properties: C, I, A, non-repudiation, privacy
2. Attacks against each of these
3. Defences: Au x 2, access control, crypto, networks
4. Coding skills and problem solving
5. Practicals: command line Linux

### Learning outcomes

1. Know how to respond to (software) security alerts.
2. Identify possible security programming errors when conducting code reviews.
3. Be able to define a methodology for security testing and use appropriate tools in its implementation.
4. Apply new security-enhanced programming models and tools which help ensure security goals, e.g., with access control, information flow tracking, protocol implementation, or atomicity enforcement.

### Safety versus security

**Safety** is concerned with ensuring bad things don’t happen **accidently**. For example, aeroplanes don’t fall out of the sky because maintenance checks are forgotten.

**Security** is concerned with with ensuring that bad things don’t happen because of *malicious actions by others*. For example, terrorists cannot drive bombs into airport departure halls.

The distinction is sometimes blurred, and the two interact in intriguing ways. *(Q. why?)*

### The challenge of software security

Software artefacts are among the most complex built.

- **Design flaws** are likely
- **Bugs** seem inevitable

Flaws and bugs lead to *vulnerabilities* which are exploited by *attackers*.

Often to learn secrets, obtain money. But many other reasons: a security risk assessment for a system should consider different attackers and their motives.
Cost estimates are difficult. But it's agreed they're increasing.

Cyber warfare is real.

Privacy is being eroded. But maybe there is hope.

Why isn't software security better?

What if Microsoft breaches its warranty? If Microsoft breaches its limited warranty, you only remedy is the repair or replacement of the software. We also have the option to refund to you the price you paid for the software (if any) instead of repairing or replacing it. Prior to refund, you must uninstall the software and return it to Microsoft, with proof of purchase.

What if Microsoft breaches any part of this agreement? If you have any basis for recovering damages from Microsoft, you can only recover only direct damages up to the amount that you paid for the software (or up to $50 USD if you acquired the software for no charge). You may not recover any other damages, including consequential, lost profits, special, indirect, or incidental damages. The damage exclusions and limitations in this agreement apply even if Microsoft knew or should have known about the possibility of the damages. Some states and countries do not allow the exclusion or limitation of incidental, consequential, or other damages, so those limitations or exclusions may not apply to you. If your local law allows you to recover other damages from Microsoft even though this agreement does not, you cannot recover more than you paid for the software (or up to $50 USD if you acquired the software for no charge).
Why (else) isn't software security better?

- Asymmetry: attackers have the advantage
  - just need to find one viable attack route
  - defenders have to anticipate all
- Attackers focus on weakest links:
  - since 1990s, network defences vastly improved
  - rise of insider threats
- Current penetrate-and-patch approach is broken
  - understandable by managers ("show me the problem!")
  - but no substitute for secure design

What's the outlook?

New frontiers:
- PCs in decline, but connected devices increasing
- Mobile new target point (convergence, mobility)
- Internet of Things: repeating same mistakes!
- Cloud: XaaS, storage
- Cyber resilience: speedy, automatic recovery
- Data sharing and its limits: privacy

Emerging new solutions:
- Build Security In, Secure By Design
- Defensive technologies continuing to evolve
- New cryptographic, verification techniques
- Old ideas re-appear: MLS, containment, isolation
- Updates: automatic, pushed patching

Delivery and assessment

We will have
- 16-18 lectures covering core course topics
- 5 lab sessions (4 core)
- 1 coursework contributing 30% of final mark
- 1 written exam contributing 70% of final mark

Lecture slides will be made available in several formats. They have numerous embedded links to useful resources (the links are more noticeable in the online versions). Lecture recordings will be available, systems permitting. These are intended as a backup.

Lab sessions

Five 2hr lab sessions (see home page):
- Weeks 3,5,7,9,11: Fri 2pm-5pm

Each session will examine software vulnerabilities: why they exist, how they can be discovered, exploited, and repaired.

Working together is encouraged. We want to foster a supportive learning environment. Students who have prior knowledge or expertise are especially welcome.

We use the SEED Labs developed at Syracuse University, New York. They are free to access for your own use.

Formative feedback during Labs

One reason to introduce labs in this course is to allow us to give face-to-face discussion and feedback on your learning.

Lab sessions will be run by me together with the course demonstrators and TA (TBC).

Coursework

The coursework will be an assignment following a similar pattern to the lab exercises: discover, exploit then repair.

1. as usual: your work should be your own
2. no publication, please do not publish solutions even after the deadline

(at least two reasons for last point).

The coursework deadline is provisionally scheduled for Week 8.
An ethical point (reminder)

Nothing in this course is intended as incitement to crack into running systems!

▶ Breaking into systems to “demonstrate” security problems at best causes a headache to overworked sysadmins, at worst compromises systems for many users and could lead to prosecution.
▶ If you spot a security hole in a running system, don’t exploit it, instead contact the relevant administrators or developers confidentially.
▶ To experiment with security holes, play with your own machine, or better, your own private network of machines.

Communications

Fast moving, evolving course:
▶ honest, constructive feedback is very welcome
▶ As with any course, I welcome questions after lectures
▶ questions by email
▶ questions on Piazza

Exam

Will follow the format:
▶ Choose 2 questions to answer from 3
▶ Two hours allowed
Towards the end of the course I will provide:
▶ a list of topics and concepts that may be examined
▶ a hint about the format of the questions
There is some guidance on the web along with a sample question.

Dimensions: practice and theory

Practice
▶ Programming securely, identifying security issues
▶ Mistakes in language, APIs, crypto, comms...
▶ Ultimately: detailed, highly specific knowledge

Theory
▶ Understand reasons for failure, ways to mitigate
▶ Understand advanced techniques, automated tools
▶ In general: transferable concepts and methods.

This is not really a “vocational” course. I hope it will give you the foundation to allow you to rapidly develop detailed specific knowledge needed later. There are a number of certification schemes for building practical knowledge.

Overview of topics

General organisation:
1. Threats
2. Vulnerabilities
3. Defences
4. Processes
5. Emerging Methods

We’ll look at details under each of these headings (in various orders).

1. Threats

What attackers want, can do
Types of bad code: malware, spyware, PUPs
How bad code gets in
Classification of vulnerabilities and weaknesses, CVE/CWEs
2. Vulnerabilities
- Overflows
- Injections
- Information leaks
- Race conditions
- Side channels and covert channels

3. Defences
- Protection mechanisms: validation, diversification, monitoring
- Trade-offs in adding protection mechanisms
- Provision for recovery

4. Processes
- Secure design principles
- Testing and reviewing to find vulnerabilities
- Assessing/measuring security of code

5. Emerging methods
- Methods and tools to find problems
- Detecting buggy patterns automatically
- Building security in, methodology and technology

Review questions
- Safety versus Security
  - Explain the difference between these two, and why ensuring security may be harder.
- Security flaws and their impact on society.
  - Explain some recent secure programming flaws that made the news and explain what the underlying problems were.
  - Discuss the fundamental reasons that software security fails and the wider questions around cyber security.

References and reading
The slides contain links which you can click on to find referenced or connected material.

References and reading will also be given for each lecture in a separate web page for that lecture. For this lecture, see here.

There is no single recommended course textbook, although a few books will be mentioned. See the page above for pointers.