MSc in

# Software Engineering

UNIVERSITY OF OXFORD

flexible, part-time, professional education

# Software Engineering

'Software engineering' is the application of scientific and engineering principles to the development of software systems: principles of design, analysis, and management. The application of these principles makes it easier to develop software that meets its requirements, even when these requirements change; to complete the development on time, and within budget; and to produce something of lasting value, by being easy to maintain, re-use, and re-deploy.

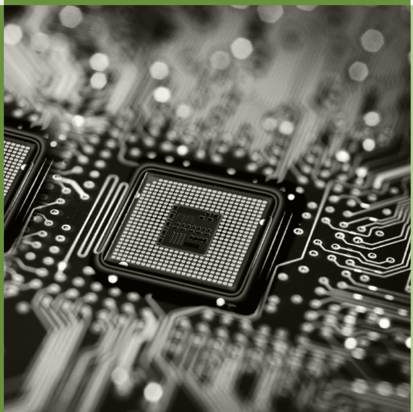
Professional Programmes at the University of Oxford teach the principles of modern software engineering, together with the tools, methods, and techniques that support their application. It offers a flexible programme of short modules to those working full time in industry or in the public sector. It is accessible to anyone with the right combination of previous education and practical experience.

The modules on the Programme can be used as individual programmes of professional training in specific subjects, or as credit towards a Master of Science (MSc) degree in Software Engineering from the University of Oxford. Students on the MSc take between two and four years to complete a minimum of ten modules, typically at a rate of three modules per year, earning a degree while in full time professional employment. The modules may be taken in any order and combination, depending upon previous experience and education.

Each module is based around a week of intensive teaching in Oxford, with some initial reading to consider beforehand, and a six-week assignment to complete afterwards. The teaching week allows you the chance to explore a subject in depth, with expert teaching and supervision, away from the demands of work and family. The reading gives you the opportunity to prepare yourselves; the assignment, an opportunity to deepen and to demonstrate your understanding.

### Module Structure

| Pre-Study | Teaching Week | Assignment |
|---|---|---|
| 4 weeks | 1 week | 6 weeks |



# Modules in Software Engineering

## Software Engineering Methods

These modules assume an understanding of the issues and challenges of software development.

### Agile Methods AGM

Agile methods are challenging conventional wisdom regarding systems development processes and practices; effectively putting process on a diet, and investing instead in people and teams. This module will enable today's software development professional to understand the heart of agility, covering both the theory and practice of agile methods such as XP and Scrum.

### Software Development Management SDM

SDM presents the skills required for the successful delivery of complex and innovative software projects, giving students a thorough grounding in the methodologies and practice of people, project, and development management, enhanced by industry guest speakers and by syndicate exercises. On completion of the module students will be able to assess a software development situation and select an appropriate management strategy.

### Process Quality & Improvement PRO

Every software development organisation needs to be focused on the delivery of quality. The software engineering discipline responds by calling for a managed process for the construction and testing of software, and for the improvement of that process. This module explains the necessary concepts within the frameworks provided by three important international standards.

### Management of Risk & Quality MRQ

Too many project planning approaches concentrate on just estimating and network aspects. This is of little value if the project is given the wrong shape or the wrong activities are chosen in the first place. The approach taught in this module builds the project from an analysis of the specific risks to be faced, in order to 'manage quality up and risk down'.

### Requirements Engineering REN

Establishing firm and precise requirements is an essential component of successful software development. Requirements may be technical, although these are often the least problematic; successful analysis requires broader investigation, addressing the human context of current and future work practices. This module covers a range of methods from 'hard' semi-formal approaches, to 'softer' people-oriented ones.

### Software Engineering Mathematics SEM

It is well known that software-based systems are extremely complex entities; it is also well known that abstraction offers the opportunity for software engineers to focus on key aspects of behaviour. This module shows how to use basic logic and set theory to describe, reason about, and understand properties of software and systems. The techniques presented are given in terms of the Z formal description technique.

### Concurrency & Distributed Systems CDS

The consequences of design decisions are particularly hard to predict in the presence of concurrency or complex patterns of interaction. This module presents a powerful technique for describing the intended behaviour of concurrent systems, and for reasoning about the interactions that emerge. The technique is based upon the language of Communicating Sequential Processes (CSP).

### Interaction Design IDE

It is important to design interactive systems taking account of the user needs and context of use. This module introduces the factors, techniques, tools and theories that will help in designing usable systems. We also cover how UX design fits within the software development life cycle, including agile approaches.

### Enterprise Architecture EAR

Managing very large information systems consisting of hundreds or thousands of systems requires a very different approach to architecture from single systems. In addition, such systems are not static, but continually evolve. During the module we will study enterprise architecture through the example of a large bank and discuss some of the wider research and standards in the field.

### Safety Critical Systems SCS

Computers are often placed in control situations within safety-critical systems. Safety is an emergent property of whole systems; software may play only a small part. This module considers the specific issues, problems and techniques associated with analysis, design, development and verification of systems that will be used in safety-critical applications.

### Performance Modelling PMO

This module presents techniques for modelling the performance of computing and communications systems. It covers tools, techniques, and analytical methods to improve the efficiency or productivity of existing or planned computer systems. In particular, it addresses the problem of how to design for the best balance of system behaviour, performance, and workload.

# Software Engineering Tools

These modules assume a familiarity with modern programming languages, tools, and techniques.

## Functional Programming FPR

In functional programming, computations are modelled as expressions rather than statements. This offers significant opportunities for parametrisation, modularisation, and optimisation, beyond those available in imperative or object-oriented programming. It also results in programs that are clearer, simpler, and often surprisingly concise. This module uses Haskell, but the techniques and concepts are useful in any language – particularly for transformations on structured data.

## Concurrent Programming CPR

The next generation of soft real-time server-side applications will only scale through massively concurrent programs executing on multi-core processors in a distributed environment. Erlang is an open source language with lightweight processes, no shared data, and built-in distribution, catering for these kinds of problem. This module uses Erlang to implement highly concurrent, massively scalable, soft real-time systems, with an emphasis on fault tolerance and high availability.

## eXtensible Markup Language XML

XML is a universal notation for creating languages, be they data or instructions. This module teaches one how to create such languages, how to validate them and how to transform them – all using the same generic framework of XML. We use a variety of practical examples that highlight fundamental issues and demonstrate how XML can be applied to a variety of Software Engineering disciplines.

## Service Oriented Architecture SOA

SOA represents a convergence of ideas from object orientation, distributed systems, and component-based development, underpinned by cross-platform protocols based largely on XML. This module provides an understanding of the strengths and weaknesses of SOA, informed by an ability to implement simple web services using a suitable development platform. It covers the definition of applications as combinations of services, and emergent properties of those compositions.

## Agile Practices in Engineering APE

In this module we cover engineering practices that support frequent, reliable delivery of software in an agile environment. We look at techniques such as continuous integration and pair programming, as well as automated quality assurance, release and deployment. We show how these methods may be applied to greenfield or legacy projects.

## Software Testing STE

Software Testing is a key aspect of the system development. This module provides all of the key knowledge and skills required to both lead a software test organisation and to be actively engaged in software testing. The module details processes, plans, methods and tools for test and presents a full life-cycle approach to testing. It covers functional, non-functional, performance and security testing.

## Database Design DAT

Database Design introduces the fundamentals of the relational model, including the relational algebra and calculus. It explores how to design relational databases that fit business requirements and covers the topics of normalization and orthogonal design. It teaches how to query a relational database using SQL, and highlights where SQL deviates from the relational model. Finally, it touches upon query optimization, transaction management and distributed databases.

## Mobile and Sensor Networks MOB

This module presents communication protocols and management techniques for wireless, mobile, and ad hoc networks. It introduces application scenarios, models and challenges of these networks; it then focuses on wireless sensor networks, and presents in-network processing and storage management techniques for resource constrained sensor systems. Finally, it introduces the concept of delay-tolerant networks, and touches upon epidemic and gossip-based protocols.

## Object Oriented Design OOD

This module teaches standard techniques for the specification and design of software systems. The notation of the Unified Modeling Language (UML) is presented, via a number of case studies. The module describes fundamental principles of object-oriented modelling, requirements development, and design, showing how to effectively use system requirements to drive design and development. It also introduces design-by-contract and the Object Constraint Language.

## Object Oriented Programming OOP

This module teaches the concepts and principles of object-orientation, with an emphasis on the impact that the concept of an “object” has on practical programming. While the language used is Java, the majority of the material covered will apply equally well to any other object-oriented language: objects, messages, inheritance and polymorphism.

## Design Patterns DPA

This is an advanced module in the structure and behaviour of object-oriented systems. It is based around the notion of a *design pattern*: an abstraction of a proven solution to a recurring problem in a specific context in system design. The module covers both the philosophy and the practice of patterns, in both design and programming.

## Software Engineering Tools

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### Algorithmics ALG

This module overviews the fundamental concepts and results underlying the science of computing. It provides both an introduction to algorithm design, discussing concrete algorithms and data structures, and also an investigation into the limits of mechanization in the form of intractability and noncomputability. The style of presentation makes intensive use of visual techniques, complementing the traditional programmatic approach to algorithmics.

### Cloud Computing and Big Data CLO

Cloud computing and big data techniques are changing the way we collect, analyze, store and use data. The aims of this module are to show how cloud computing and big data techniques can be used to solve massive scale problems. This module looks at the theoretical and practical technologies behind big data and cloud computing, such as mapreduce, and approaches to building applications and managing them on the cloud.

### Embedded Software and Systems ESS

Over 99% of processors manufactured end up in embedded systems, ranging from washing machines to traffic lights. The aim of this module is to illustrate how the process of software development for embedded systems is fundamentally different to conventional software, due to the tight coupling between hardware and software, and be able to apply tools and techniques to overcome these issues.

### Semantic Technologies STC

Semantic Technologies are a family of recently emerged technologies particularly well suited for managing and sharing large volumes of heterogeneous, rapidly evolving data. This is an introductory module covering the Semantic Web languages RDF(S), OWL, and SPARQL. The module is a combination of lectures covering both practical and theoretic aspects and extensive modelling and querying of semantic knowledge bases.

### Robust programming ROP

This module presents foundational techniques for reasoning about the behaviour of objectoriented and imperative programs. Students will learn how these techniques can be employed during the design phase or at later stages of development. In particular, they will see how semantics can be formally defined and how static checking works, and will be introduced to the design-by-contract approach.

# Modules in Software and Systems Security

A range of other modules are available, addressing subjects in software and systems security. These may address complementary topics, or provide useful background, for the study of software engineering.

### Security Principles SPR

This module teaches the fundamental principles of information and systems security, and is often used as an introduction to the Programme. It explores a wide range of security technologies, examines security standards and expectations, and explains techniques for the evaluation of security requirements and solutions. It places theoretical work on protocol design, cryptography, and information flow firmly in the context of existing and emerging practice, with an emphasis upon integration and usability.

### Design for Security DES

Security is a system-level property, and emerges from the coordinated design of components and processes. This module shows how a range of factors, from architectural patterns to detailed technical controls, can be considered together in the production of cost-effective solutions. It addresses the challenge of providing security, through a combination of infrastructure, mechanisms, and procedures, while satisfying requirements for functionality and usability.

### Security Risk Analysis & Management RIS

The concept of risk is central to software and systems security. Understanding the ways in which systems are vulnerable to threats needs to inform the selection and prioritisation of security measures. This module teaches a principled approach to risk analysis, explores the techniques and practices of risk management, and demonstrates their application through a realistic set of examples and case studies.

### Forensics FOR

The investigation of computer crime is a delicate, involved process that requires a deep understanding of the evidential standards expected in circumstances where electronic forensic data is to be used. This module describes the current best practice in understanding and deconstructing an attack whilst preserving evidence, and explores how to design and evaluate systems in order to facilitate forensic examination. It combines a strong overview of principles with some illustrative practical work, recovering data using necessarily low-level tools.

## Trusted Computing Infrastructure TCI

A secure system is the product of numerous layers that operate together to provide in-depth protection. This module looks at the various platforms upon which a secure system operates, with an emphasis on practical and repeatable means of implementing these platforms securely. It examines roots and chains of trust, operating systems security, trusted platforms, and virtualisation for security. It shows how these are applied to secure networking, remote working, trusted storage, and remote computation in grids and clouds.

## People & Security PAS

Many failures in security can be attributed to human weakness, misunderstanding, or failure to grasp the importance of prescribed processes and procedures. The interaction between people and technology often presents a significant challenge to secure operation. This module teaches techniques drawn from human-computer interaction and psychology, addressing this challenge within the context of hard, technical decisions.

## Network Security NES

Networks are a potential vector for many forms of attack, and are an ideal location for threat mitigation and isolation technologies. This module teaches approaches to the prevention, detection, mitigation, and remediation of security problems in the network at each layer, as well as looking at cross-cutting concerns across a complete networking stack. It examines the strengths and weaknesses of boundary protections, intrusion detection and prevention, and privacy-preserving routing.

## Data Security DAS

New technologies make it possible to capture increasingly detailed, personal information: about customers, patients, and citizens. As new ways of linking and using this information emerge, so too do concerns about the security of the corresponding data. This module explores the potential impact of existing and future legislation upon data storage and processing, and presents practical approaches to the secure management of personal and other information in databases and applications.

## Security Incident Management SIM

A key ingredient of successful security and risk programmes is effective management of security-related incidents. ncidents range from the small and predictable, which can be eliminated through operation controls, to the large and unpredictable, where standard management controls and mechanisms may not work. This module teaches the principles of incident management in practice and identifies key themes for effective response to the range of events and triggers that impact upon businesses, governments, and individuals.

## Secure & Robust Programming SRO

Many failures and vulnerabilities arise at the programming level. These are often due to inadequate handling of exceptional situations, poor understanding of the details of the programming language in use, and incomplete descriptions of the interfaces between components. This module aims to improve the practitioner's capability in writing and reviewing code, through a thorough understanding of static analysis, run-time assertion checking, and compile-time verification.

## Cloud Security CLS

The provision of automated self-managed services – for software, platforms, and infrastructure – relieves local administration of many security concerns, yet also removes from them many of the tools and controls they expect to use, while introducing new threats and adversaries. This module reviews the architectural principles of cloud computing, describes the threats and security controls possible at each level of abstraction, and addresses cloud management services for trustworthy, secure, and resilient operation with minimal intervention.

## Building Information Governance BIG

To govern information now requires mastery of a diverse, often international, portfolio of legal rules, technology standards, business policies, and technology, all applied across increasingly complex, distributed systems. This module introduces participants to a structured design approach that will enable strong, responsive and resilient information governance to be incorporated into the design and management of digital assets.

## Mobile Systems Security MSS

Mobile devices present distinctive challenges for security, including problems of device association, power constraints, and restricted interfaces. Mobile applications often incorporate both local and remote services, complicating the management and enforcement of security policies. This module presents a range of techniques for the design and implementation of secure mobile applications, balancing the requirements of functionality, security, resource utilisation, and privacy.

## Security in Wireless Networks SWN

The purpose of this module is to familiarise participants with threats, vulnerabilities, and security countermeasures of existing and upcoming wireless and mobile networks. The topics covered include a wide range of mainstream wireless technologies, such as, WLAN, Bluetooth, GSM, and UMTS. In addition, the module will explore security and privacy problems, and potential solutions of new and emerging wireless technologies, such as ZigBee, wireless mesh networks, and RFIDs.

*"The MSc looks impressive on a resume. It has certainly opened a number of doors for me"*

## MSc in Software Engineering

A postgraduate degree is evidence of individual ability and understanding beyond the expectations of industry training, undergraduate education, and professional experience. It is a demonstration that you have achieved a mastery of the subject: that you can select, adapt, and apply appropriate techniques; that you can evaluate what is, and what is not, working; that you can anticipate, and facilitate, change. This kind of evidence can be invaluable in the workplace: to lend additional authority to your opinions; to better establish your credentials; and to reassure others as to your suitability for new roles and responsibilities.

A postgraduate degree is also an opportunity for personal development: a chance to test your ideas and intuitions, to experiment with new tools and techniques, and to make new connections between theory and practice. It is an environment in which you can take a step back from the immediate demands and compromises of your latest project, and think more strategically about the nature of the problems you encounter, and how they might be solved more efficiently, and more effectively. This kind of opportunity can be invaluable in your personal life, bringing new confidence, skills, and inspiration.

## The University of Oxford

The modules take place in a purpose-built teaching facility in Oxford, part of the new building for the Department of Computer Science. Each module is taught by a subject expert: a member of faculty, or an industrial practitioner. The students will bring a varying combination of expertise and experience: some will be developers, managers, or consultants; others will be architects, designers, or testers. Class sizes are kept small to facilitate learning and interaction.

All students are members of the University's Department of Computer Science, a recognised centre of excellence for teaching and research in computing and related disciplines. The University of Oxford was the first university in the English-speaking world, and is consistently ranked among the ten leading universities globally.

Each student will be a member also of one of the Oxford colleges. Several colleges offer places for this module, but most students choose to belong to Kellogg College, a college established specifically to meet the expectations of students on professional and non-residential programmes. If a student on the programme already has a degree from Oxford, and was a member of a different college for their previous period of study, then they may prefer to return to that college. All of the teaching faculty whose teaching is primarily for part-time students are themselves members of Kellogg.

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DEPARTMENT OF
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# Studying on the Programme

## Getting Started

All of the modules described above can be taken as individual programmes of professional training. You may book a place on any module on-line, or by calling the Programme Office. One month before the teaching week – or upon payment of the invoice, if later – you will be sent some initial reading material. The teaching week itself runs from 9am to 5pm from Monday to Thursday, and from 9am to 12.30pm on Friday. At the end of the week, you will be given an assignment task: you can take this, and get feedback on your submission, even if you have no plans to use the module as credit towards a postgraduate qualification.

To study for a postgraduate qualification – the MSc in Software Engineering – you need to make a formal application to the University. You can take up to two modules before doing this and still use them as credit, provided that you complete the assignments. If you appear to meet the admission criteria, you will then be invited for an interview, where you will have the opportunity to discuss your expectations, your study plans, and your readiness to take part in a programme of part-time, professional education. If your application is successful, then you may be admitted at the beginning of the next term: in January, April, or October.

The admission criteria are straightforward: at a minimum, we expect applications to have either a degree-level qualification in a related discipline, or a substantial record of practical achievement in the area of software development in a professional context. The majority of those accepted have both previous higher education and industrial experience, but applications are welcome from software practitioners without formal qualifications, and from newly qualified professionals. We will ask also for at least two references, one of which will normally come from your current employer.

**www.cs.ox.ac.uk/professional/apply**

## Module Selection

Each of the modules is designed to work as a separate programme of learning, and modules in related subjects can be taken in any order. Some of the modules assume familiarity with material taught in others: if you are not already familiar with this material, then you may obtain greater value by attending the other modules first. Advice and guidance on module selection can be obtained from the Programme Office.

*"I work in IT, but my background is in physics. This was an ideal opportunity to get a formal qualification in the area that I work in."*

## Academic Awards

To be awarded an MSc in Software Engineering, you will need to attend ten modules, complete the corresponding assignments, and write a dissertation based upon a research project of your own design. You have four years from the date of admission to do this, although more time will be allowed in exceptional circumstances. Most students take three or four years to complete the MSc; some take two years, which is the minimum period allowed between admission and graduation.

The security modules offered by the Programme can be used for the MSc in Software Engineering. If you prefer to take the majority of your modules on security subjects, and write a dissertation on the same topic, then you can choose to be examined instead for the MSc in Software and Systems Security.

If your plans change while you are studying and you are no longer able to meet the requirements for an MSc, even if more time were allowed, then you may choose to be examined for a lower graduate qualification. Attendance at four (or eight) modules, and the successful completion of the corresponding assignments, can lead to the award of a Postgraduate Certificate (or Postgraduate Diploma) in Software Engineering. Should you later return to study on the Programme, you will be able to use these modules as credit towards an MSc.

## Fees

There is a fee for each module attended, which covers materials and lunches during the teaching week, and the assignment, but not accommodation. This is payable strictly in advance.

There is an additional registration fee for students on the MSc in Software Engineering. This may be paid in up to four annual instalments.

These fees are revised each year, typically in line with the rate of inflation in the UK.

## Key Facts

- a flexible programme in software engineering leading to an MSc from the University of Oxford
- a choice of over 40 different modules, each based around an intensive teaching week in Oxford
- MSc requires 10 modules and a dissertation, with up to four years allowed for completion
- applications welcome at any time of year, with admissions in October, January, and April.

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