Computer Science

Masters programmes in ‘Big Data’

- Computational Finance (with a Year in Industry)
- Data Science and Analytics (with a Year in Industry)
- Machine Learning (with a Year in Industry)

ROYAL HOLLOWAY UNIVERSITY OF LONDON

"A significant constraint on realising value from big data will be a shortage of talent, particularly of people with deep expertise in statistics and machine learning,"
Big Data: The next frontier for innovation, competition, and productivity

McKinsey Global Institute, 2011

Contents

www.royalholloway.ac.uk/computerscience
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Athena SWAN Bronze Award

The Department has received an Athena SWAN Bronze award in recognition of our commitment to increasing the participation of women in Computer Science.

Big Data

Big Data is now part of every sector and function of the global economy – from retailers, to health providers, to financial services and insurance, and to governmental and non-governmental organisations. Planning and strategic decision-making processes rely on large pools of data that need to be captured, aggregated, stored, and analysed. However, people with the right set of skills – data scientists – are in short supply and high demand.

Our Masters in 'Big Data' will prepare you for what the *Harvard Business Review* 2012 described as the 'sexiest profession of the 21st century'. You will acquire all the knowledge and skills that employers look for to implement and drive their data strategies.

You will also be taught by world-leading academics and interact with professionals, including former Royal Holloway students and post-docs who went on to work for Google, Microsoft, Amazon, and Facebook.

Research in Machine Learning at Royal Holloway has been at the source of the 'Big Data' analytics revolution; we developed both fundamental theory and practical algorithms that have fed into the analytics methods and techniques that are in use today.

- 'Support vector machines' – SVMs – are a widely commercially used machine-learning method; SVMs were originally invented by V. Vapnik and A. Chervonenkis, who were subsequently both professors here (now emeriti). Royal Holloway developed the first widely distributed open-source SVM implementation. The original reference monograph (by Vapnik in 1998) and the first accessible and widely read textbook (by N. Cristianini and J. Shawe-Taylor, 2000) were written by professors in the Department.
- V. Vovk was an originator of 'competitive learning'; in this paradigm, the learner makes no statistical assumptions about the data at all – the data can even be generated by a hostile adversary. The learner's aim is to do nearly as well as the best of a comparison class of predictors. This theory has led to surprising applications such as 'universal portfolio' investment algorithms.
- A. Gammerman, G. Shafer and V. Vovk developed 'conformal prediction', a radically new method of estimating the accuracy of each prediction as it is made. This learning method has been recently trialled for recognising plasma instabilities in an experimental nuclear fusion reactor.
- C. Watkins was an originator of reinforcement learning, and developed 'Q-learning'; this work is fundamental to planning and control.

Highlights

Optional industrial placements are available (up to one year), which will allow you to gain experience and acquire skills that can only be picked up in a real work environment.

A weekly seminar series runs in parallel with the academic programme, which includes talks by professionals and academics in a variety of application areas as well as workshops that will train you to find a placement or a job and lead a successful career.

You will have 24/7-access to labs with a state-of-the-art large-scale data storage and processing infrastructure.

Royal Holloway provides a unique environment in which to study

We have been voted as one of the twelve most beautiful universities in the world.

We are located in the 'M4 corridor', west of London, a major high-technology hub also called 'England's Silicon Valley'. Many companies and organisations visit the campus throughout the year to participate in job fairs, offer placements, give presentations to our students, or engage with our staff in cutting-edge collaborative research.

We are the safest university in the London area according to the Complete University Guide 2014.

We are placed 12th in the UK (102nd in the World) by the Times Higher Education World University Rankings 2014, 1st in the UK (4th in the World) for International Outlook, and 1st in the UK (8th in the World) for citations, which measures the influence that research has in the world.

12th

Our Masters degrees

- **Data Science and Analytics** – This degree, offered by the Department of Computer Science, will teach you both the foundational aspects and the practical skills that prepare you for handling and analysing different types of data in different fields, thus responding to the needs of a huge variety of companies and organisations from retailers such as Tesco or Amazon, to manufacturers like BMW, health-care providers, or public administration.
- **Computational Finance** – This degree, offered by the departments of Computer Science and Economics, allows you to specialise in modern quantitative finance and computational methods for financial modelling, which are demanded for jobs in asset structuring, product pricing as well as risk management.
- **Machine Learning** – This degree, offered by the Department of Computer Science, allows you to develop a deeper understanding of the science of systems that can learn from data, which companies such as Facebook, Google, Microsoft and Yahoo require to create, innovate, and define the next generation of search and analysis technologies.

rhul.ac.uk/computerscience/prospectivestudents/postgraduatetaught/bigdata.aspx

Programme structure

	Computational Finance	Data Science and Analytics	Machine Learning
Term 1	• Data Analysis • Programming for Data Analysis • Foundations of Finance • Database Systems (*) • Electives	• Data Analysis • Programming for Data Analysis • Object-Oriented Programming (*) • Database Systems (*) • Electives	• Data Analysis • Programming for Data Analysis • Computer Learning (*) • Object-Oriented Programming (*) • Electives
Term 2	• Investment Portfolio Management • Electives	• Large-scale Data Storage and Processing • Electives	• On-line Machine Learning • Inference or Applied Probability • Electives
Exams			
Placement (for the Year-in-Industry degrees), up to one year			
Project (12 weeks)			

Notes

- Courses marked with (*) are available (and compulsory) only for certain students depending on their background.
- Electives are chosen among the main and other courses to complete each term to a total of 60 credits. Restrictions may apply to the choice of courses depending on the student's background.
- The project is a major individual piece of work in the area of the chosen programme.
- Progression to the placement is conditional on good academic performance

Course contents

Area	Course Name	Cred	Term	CF	DSA	ML
CS	Computer Learning	10	1	(2)	(2)	(1)
CS	Data Analysis	20	1	C	C	C
CS	Database Systems	10	1	(1)	(1)	(2)
CS	Data Visualization	10	2	O	O	O
CS	Large-scale Data Storage and Processing	20	2	O	C	O
CS	Methods of Computational Finance	10	1	(2)	(2)	(2)
CS	Object-Oriented Programming	10	1	(2)	(1)	(1)
CS	Programming for Data Analysis	10	1	C	C	C
CS	On-line Machine Learning	20	2	O	O	C
E	Foundations of Finance	20	1	C	O	O
E	Investment and Portfolio Management	20	2	C	O	O
M	Inference	20	2	O	O	(3)
M	Applied Probability	20	2	O	O	(3)

(1) This course is available (and compulsory) only for certain students depending on their background

(2) This course is available (and optional) only for certain students depending on their background

(3) Students need to take at least one of these two courses

Examples of other courses
(can be chosen as electives subject to availability and timetabling; some are not available to certain students depending on their background; terms can change)

Area	Course Name	Cred	Term
CS	Bioinformatics	10	2
CS	Business Intelligence	10	2
CS	Computational Optimisation	10	2
CS	Internet and WebTechnologies	10	1
CS	Multiagent Systems	10	2
CS	Service-Oriented Computing	10	2
CS	Advanced Data Communication	10	1
E	Decision Theory and Behaviour	20	2
E	Financial Econometrics	20	2
E	Corporate Finance	20	1
E	Fixed Income Sec.&Derivatives	20	2
E	Micro-econometrics	20	2
IS	Computer Security	20	1
IS	Digital Forensics	20	2
IS	Introduction to Cryptography	20	1
IS	Network Security	20	1
IS	Security Management	20	2
IS	Security Technologies	20	1
IS	Security Testing	20	2
IS	Smart Cards	20	2
IS	Software Security	20	2
M	Topics in Applied Statistics	20	1

Areas:
CS – Computer Science, E – Economics, IS – Information Security, M – Mathematics

Outline of main course contents

Applied Probability – The course introduces the student to a range of examples of probabilistic methods used to model systems that exhibit random behaviour. Key classes of models covered include Poisson processes, renewal theory, and Markov processes.

Computer Learning – The course provides an in-depth coverage of linear and kernel methods of machine learning with a focus on support vector machines and regression. The course enables the students to implement and apply the methods and appraise the results.

Data Analysis – The course addresses fundamentals of data analysis with a focus on statistical learning. It covers all stages of data analysis from preprocessing to interpreting the results. It will teach students to develop, validate, and use effectively machine-learning and statistical models and algorithms.

Database Systems – This course is aimed at students with a weaker background on the core concepts of data and information management. It covers the entity-relationship model, relational database design, SQL (DDL, DML) and DCL relational data bases.

Foundations of Finance – The course covers the structure of financial markets, the instruments traded and the participants. It provides students with tools to analyse how financial markets function and how problems arise from their operations..

Inference – This course covers the main principles and methods of statistics. It offers students an introduction to parametric estimation and hypothesis testing. It covers key concepts such as maximum likelihood, method of moments, Bayes estimators, sufficiency, unbiasedness, efficiency, asymptotic properties of maximum likelihood estimators.

Methods of Computational Finance – The course enables the students to apply mathematical and computational methods for pricing and hedging derivative securities and portfolios of securities.

Object-Oriented Programming – The course covers programming in Java and general principles of object-oriented programming. It is aimed at students with weaker programming skills.

Investment and Portfolio Management – The course covers the underlying theory and empirical evidence in portfolio management in the finance sector. Students will acquire an understanding of how funds are allocated when constructing a portfolio.

Large-scale Data Storage and Processing – The course addresses: advanced concepts in distributed systems, networking, and cloud computing; principles of large-scale data storage and processing; NoSQL Data Stores (MongoDB, and others); distributed processing frameworks (Hadoop, Pig, and others); and the design and implementation of an OLAP solution.

On-line Machine Learning – The course addresses the on-line framework of machine learning in which the learning system learns and issues predictions or decisions in real time, perhaps in a changing environment. Students will learn how to develop and use universal prediction algorithms, including universal strategies for dynamic investment, and how predictions can be complemented with provably valid measures of their accuracy and reliability.

Programming for Data Analysis – The course covers MATLAB and R, the main systems for numerical programming and data analysis used in industry and academia. At the end of the course students will be able to use MATLAB and R in solving efficiently important classes of problems arising in data analysis.

"My personal advisor was helpful when I needed advice. The lecturers are clearly passionate about their subject and that helped with my enjoyment and understanding of the topics. Overall, I have loved my time at Royal Holloway and will miss it immensely." *Computer Science Graduate, 2013*

Skills acquired

If you follow the MSc in Data Science and Analytics or the MSc in Machine Learning, you will have the opportunity to acquire the following skills:

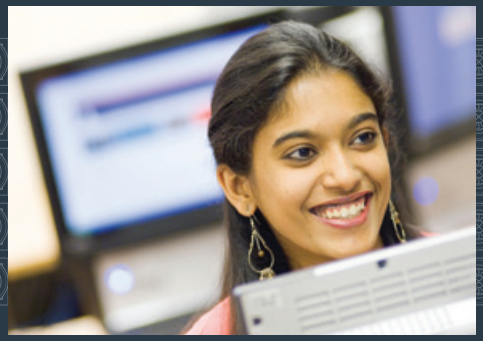
- A highly analytical approach to problem solving.
- A strong background in data modelling and business intelligence.
- Knowledge of computational and statistical data analysis.
- A background in machine learning, statistics, and data mining.
- Ability to develop, validate, and use effectively machine learning models and statistical models.
- Ability to apply machine learning and data mining techniques to Information Retrieval and Natural Language Processing.
- Knowledge of and ability to work with software to automate tasks and perform data analysis.
- Knowledge of and ability to work with structured, unstructured, and time-series data.
- Ability to extract value and insight from data.
- Knowledge of and ability to work with methods and techniques such as clustering, regression, support vector machines, boosting, decision trees, neural networks.
- Appreciation and knowledge of non-statistical approaches to data analysis and machine learning.
- Ability to work with software packages such as MATLAB and R.
- Knowledge of and ability to work with Relational Database Systems and SQL.
- Understanding of and ability to work with highly-scalable data-storage paradigms, such as NoSQL Data Stores (MongoDB, Cassandra, HBase, ...) and Distributed Hash Tables.
- Knowledge of and ability to work with modern tools for massively distributed data processing, such as Hadoop and Pig.
- Familiarity with Cloud Computing tools for large-scale data storage and processing (such as Amazon S3, EC2 and Elastic MapReduce).

If you follow the MSc in Computational Finance, you will have the opportunity to acquire the following skills:

- Knowledge of the working of financial markets and their role in the context of the global economy.
- Knowledge of modern mathematical and computational techniques used in finance.
- Knowledge of key ideas, principles, and methods of machine learning and their applications in finance.
- Ability to apply methods of computational finance to practical problems in computational finance, including pricing of derivatives and risk assessment.
- Ability to analyse and critically evaluate methods and general principles of computational finance and their applicability to specific problems; ability to critically evaluate validity and practicality of results.
- Ability to analyse and critically evaluate applicability of machine learning algorithms to problems in finance.
- Ability to implement methods of computational finance and machine learning using object-oriented programming languages and modern data management systems.
- Ability to work with software packages such as MATLAB and R.
- Knowledge of and ability to work with Relational Database Systems and SQL.
- Understanding of and ability to work with highly-scalable data-storage paradigms, such as NoSQL Data Stores (MongoDB, Cassandra, HBase, ...) and Distributed Hash Tables.
- Knowledge of and ability to work with modern tools for massively distributed data processing, such as Hadoop and Pig.
- Familiarity with Cloud Computing tools for large-scale data storage and processing (such as Amazon S3, EC2 and Elastic MapReduce).

If you choose to take a placement, you will acquire in addition:

- Work experience and appreciation of how your work fits into the organizational and development processes of a company.



Other information

Industrial placement – All programmes are offered with or without an industrial placement:

- Your placement will take up to one year and your visa will cover the two years of the programme.
- The placement attracts a salary and is assessed as part of your degree.
- You will be assigned a supervisor by the host company, who is responsible for directing your work.
- You will be assigned an academic supervisor, who visits to check if you are integrating successfully and the type of work being undertaken is appropriate, and supports you in general during your placement.
- If you cannot or decide not to take a placement, you revert to the normal one-year degree.

Although the responsibility for finding a placement is ultimately yours, our Careers Service will help you identify suitable opportunities from a large database of companies, make applications and prepare for interviews. Fairs are organised and companies visit to offer placements, and we regularly post offers on our Facebook group.

Please note that progression to the placement is conditional to good academic performance during the taught part of your programme.

Entry requirements – Candidates should have, or expect to gain, at least a good second-class honours degree in Computer Science, Economics, Engineering, Mathematics, Physics, or other subjects that include a strong element of mathematics or computing. Industrial experience may compensate for lesser degrees or lack of technical qualification, as will demonstrated programming skills and a strong ability to learn. Non-native English-speaking applicants should hold IELTS 6.5 or equivalent.

Fees and funding – Studying for a Masters takes one year (12 months), up to two years if you take an industrial placement. Please check our web site for the fees that apply to your year of entry. If you join a Year-in-Industry programme, you will pay the one-year fee plus a small fee in the second year.

Please note that you will be asked to make a deposit to accept your offer and receive the documentation that will enable you to obtain a visa.

Check **www.rhul.ac.uk/studyhere/scholarships.aspx** for scholarship schemes that may be available to you.

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"By 2015, 4.4 million IT jobs globally will be created to support Big Data, generating 1.9 million IT jobs in the United States."

Peter Sondergaard, senior vice president at Gartner and global head of Research, 2012

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