Business Analytics MSc

Vrije Universiteit Amsterdam - Faculteit der Exacte Wetenschappen - M Business Analytics - 2017-2018

More information

- All compulsory courses and electives you find in the year schedule;
- A complete description of the programme you find in the Teaching and Examination Regulations;
- For more information about the programma you can contact the academic advisor (VU students only);
- As a VU student you need to register for all courses via VUnet. Only after you completed your enrollment for the study programme you can register for courses;
- More information on all the courses you find through the links below.

Inhoudsopgave

BA Dual Variant

The dual Master's program combines work and study. During the first 16 months of this program the student is employed part time, and studies part time. The work has to be relevant for the study and the dual work period is granted with 12 EC. Moreover, it is possible to do the Research Paper BA on a case-study that is work related, provided the case-study is combined with a sound theoretical basis. Often, the external master project is carried out at the same organization as the dual work period. The students can only start their internship or Master Project after having finished the compulsory Research Paper BA (6 EC) and having completed all but possibly one program components.

Admission to the dual Master's program is granted to those who have a Business Analytics Bachelor's degree. For those with another university Bachelor's degree, such as Mathematics, Econometrics, Computer Science, or a Bachelor's degree from an institute of higher education, admission may be granted on an individual basis. Those seeking admission to the dual Master's program should realize that admission also depends on obtaining suitable employment. The VU has contacts with a number of companies that are interested in participating in this program.

For more information concerning the dual master's program, contact the coordinator for the external master's project or the master coordinator.

The program consists of 120 European credit points (EC)
- compulsory courses 78 EC (including a Master Project of 36 EC)
- constrained selection 24 EC
- optional courses 18 EC

Note: Every program, including the choice of optional courses, has to be discussed and agreed upon with the master coordinator and approved by the Examination Board.

Opleidingsdelen:

- Master BA The Dual Master's Programme - Compulsory selection Mathematics and BA
- M Business Analytics suggested elective courses
- M Business Analytics Dual variant compulsory courses

Master BA The Dual Master's Programme - Compulsory selection Mathematics and BA

There is a constrained selection of at least four courses (24 EC) from this list below.

Note: Every programme, including the choice of optional courses, has to be discussed and agreed upon with the master coordinator and approved by the Examination Board.

Vakken:

Naam	Periode	Credits	Code

Advanced Linear Programming	Periode 4+5	6.0	X_400326
Business Process Analytics	Periode 4	6.0	X_400650
Computational Intelligence	Periode 2	6.0	XM_417015
Continuous Optimization	Periode 1+2	6.0	X_400446
Entrepreneurship in Data Science and Analytics	Periode 4+5	6.0	X_405122
Evolutionary Computing	Periode 1	6.0	X_400111
Financial Modelling and Derivatives	Periode 4	6.0	E_IBK3_FMD
Heuristic Methods in Operations Research	Periode 1+2	6.0	X_418006
Investments	Periode 5	6.0	E_EBE3_INVES
Machine Learning 1	Periode 1	6.0	XMU_418144
Mathematical Systems and Control Theory	Periode 1+2	6.0	X_400180
Optimization of Business Processes	Periode 4+5	6.0	X_400422
Performance of Networked Systems	Periode 4	6.0	X_405105
Project Optimization of Business Processes	Periode 3	6.0	X_400213
Quantitative Financial Risk Management	Periode 4	6.0	E_FIN_QFRM
Scheduling	Periode 4+5	6.0	X_400396
Stochastic Optimization	Periode 1+2	6.0	X_400336
Stochastic Processes for Finance	Periode 1+2	6.0	X_400352

M Business Analytics suggested elective courses

Vakken:

Naam	**Periode**	**Credits**	**Code**
Computational Finance	Periode 4	6.0	XMU_418045
Distributed Systems	Periode 2	6.0	X_400130
Financial Markets and Institutions	Periode 4	6.0	E_EBE3_FMI
International Financial Management	Periode 5	6.0	E_IBK3_IFM
Programming Large-scale Parallel Systems	Periode 1	6.0	XM_40017
Statistics for High-Dimensional Data	Periode 4+5	6.0	X_405113
Statistics for Networks		6.0	X_405110
Text Mining	Periode 4	6.0	L_PABAALG002

M Business Analytics Dual variant compulsory courses

Both the Research Paper BA (6 EC) and the Master Project (36 EC) may be work-related. The work period consists of 12 EC. The total work related credit points has therefore a maximum of 54 EC.

Compulsory alongside the mentioned courses, are a compulsory choice (24 EC) and optional courses (18 EC) to complete 120 EC.

Note: Every programme, including the choice of optional courses, has to be discussed and agreed upon with the master coordinator and approved by the Examination Board.

Vakken:

Naam	Periode	Credits	Code
Applied Analysis: Financial Mathematics	Periode 1+2	6.0	X_400076
Applied Stochastic Modeling	Periode 1+2	6.0	X_400392
Data Mining Techniques	Periode 5	6.0	X_400108
Dual Workperiod	Ac. Jaar (september)	12.0	XM_41010
Master Project Business Analytics	Ac. Jaar (september)	36.0	X_400459
Research Paper Business Analytics	Ac. Jaar (september)	6.0	X_400206
Statistical Models	Periode 1+2	6.0	X_400418

Professional track

The emphasis will be on a broad and multidisciplinary education, preparing the student for a role as an academically trained quantitative professional in a multidisciplinary organization. Even so, the possibility to continue after the Master in a PhD program exists also for these variants.

Business Analytics is a two-year program. The first six months are devoted to compulsory courses. Over the next twelve months, you will deepen your knowledge in the three fields of expertise after which you will have the opportunity to specialize in business process optimization, computational intelligence and financial risk management. Combining the knowledge you acquire and applying it to practical situations plays an essential role in the program. As such, the Master's degree is concluded with a six-month individual internship at a company (the Master's project). The students can only start their internship or Master Project after having finished the compulsory Research Paper BA (6 EC) and having completed all but possibly one program components.

The progam consists of 120 European creditpoints (EC)
- compulsory courses 72 EC (including a Master Project of 36 EC)
- compulsory choice 30 EC
- optional courses 18 EC

Note: Every program, including the choice of optional courses, has to be discussed and agreed upon with the master coordinator and approved by

the Examination Board.

Opleidingsdelen:

- Compulsory Selection
- Compulsory Courses
- M Business Analytics suggested elective courses

Compulsory Selection

There is a constrained selection of at least five courses (30 EC) from this list below.

Note: Every program, including the choice of optional courses, has to be discussed and agreed upon with the master coordinator and approved by the Examination Board.

Vakken:

Naam	Periode	Credits	Code
Advanced Linear Programming	Periode 4+5	6.0	X_400326
Business Process Analytics	Periode 4	6.0	X_400650
Computational Intelligence	Periode 2	6.0	XM_417015
Continuous Optimization	Periode 1+2	6.0	X_400446
Entrepreneurship in Data Science and Analytics	Periode 4+5	6.0	X_405122
Evolutionary Computing	Periode 1	6.0	X_400111
Financial Modelling and Derivatives	Periode 4	6.0	E_IBK3_FMD
Heuristic Methods in Operations Research	Periode 1+2	6.0	X_418006
Investments	Periode 5	6.0	E_EBE3_INVES
Machine Learning 1	Periode 1	6.0	XMU_418144
Mathematical Systems and Control Theory	Periode 1+2	6.0	X_400180
Optimization of Business Processes	Periode 4+5	6.0	X_400422
Performance of Networked Systems	Periode 4	6.0	X_405105
Quantitative Financial Risk Management	Periode 4	6.0	E_FIN_QFRM
Scheduling	Periode 4+5	6.0	X_400396
Stochastic Optimization	Periode 1+2	6.0	X_400336
Stochastic Processes for Finance	Periode 1+2	6.0	X_400352

Compulsory Courses

The following list contains the compulsory courses (72 EC).

Vakken:

Naam	Periode	Credits	Code
Applied Analysis: Financial Mathematics	Periode 1+2	6.0	X_400076
Applied Stochastic Modeling	Periode 1+2	6.0	X_400392
Data Mining Techniques	Periode 5	6.0	X_400108
Master Project Business Analytics	Ac. Jaar (september)	36.0	X_400459
Project Optimization of Business Processes	Periode 3	6.0	X_400213
Research Paper Business Analytics	Ac. Jaar (september)	6.0	X_400206
Statistical Models	Periode 1+2	6.0	X_400418

M Business Analytics suggested elective courses

Vakken:

Naam	Periode	Credits	Code
Computational Finance	Periode 4	6.0	XMU_418045
Distributed Systems	Periode 2	6.0	X_400130
Financial Markets and Institutions	Periode 4	6.0	E_EBE3_FMI
International Financial Management	Periode 5	6.0	E_IBK3_IFM
Programming Large-scale Parallel Systems	Periode 1	6.0	XM_40017
Statistics for High-Dimensional Data	Periode 4+5	6.0	X_405113
Statistics for Networks		6.0	X_405110
Text Mining	Periode 4	6.0	L_PABAALG002

Advanced Linear Programming

Vakcode	X_400326 (400326)
Periode	Periode 4+5
Credits	6.0
Voertaal	Engels
Faculteit	Faculteit der Exacte Wetenschappen
Coördinator	prof. dr. L. Stougie
Examinator	prof. dr. L. Stougie
Docent(en)	prof. dr. L. Stougie
Lesmethode(n)	Hoorcollege

Niveau	400

Inhoud vak
This course is part of the joint national master programme in mathematics. For schedules, course locations and course descriptions see https://elo.mastermath.nl/?lang=en

Doelgroep
mMath

Intekenprocedure
You have to register your participation in each Mastermath course via https://elo.mastermath.nl/login/
Registration is mandatory and absolutely necessary for transferring your grades from Mastermath to the administration of your university.

Applied Analysis: Financial Mathematics

Vakcode	X_400076 (400076)
Periode	Periode 1+2
Credits	6.0
Voertaal	Engels
Faculteit	Faculteit der Exacte Wetenschappen
Coördinator	prof. dr. A.C.M. Ran
Examinator	prof. dr. A.C.M. Ran
Docent(en)	prof. dr. A.C.M. Ran
Lesmethode(n)	Hoorcollege
Niveau	400

Doel vak
The course aims to introduce the student to several aspects of the mathematical theory of option pricing.

Inhoud vak
This course gives an introduction to financial mathematics.
The following subjects will be treated:
- introduction in the theory of options;
- the binomial method;
- introduction to partial differential equations;
- the heat equation;
- the Black-Scholes formula and applications;
- introduction to numerical methods, approximating the price of an (American) option.

Onderwijsvorm
Lectures, exercises, discussion of exercises.

Toetsvorm
Homework exercises and final examination

Literatuur
The Mathematics of Financial Derivatives, A Student Introduction, by Paul Wilmott, Sam Howison, Jeff Dewynne. Cambridge University Press.

In addition, lecture notes will be made available for several topics which are not treated in the book.

Aanbevolen voorkennis
Calculus and Linear Algebra

Doelgroep
3W, mMath, mBA, 3Ect

Applied Stochastic Modeling

Vakcode	X_400392 (400392)
Periode	Periode 1+2
Credits	6.0
Voertaal	Engels
Faculteit	Faculteit der Exacte Wetenschappen
Coördinator	dr. R. Bekker
Examinator	dr. R. Bekker
Docent(en)	dr. R. Bekker
Lesmethode(n)	Hoorcollege, Werkcollege
Niveau	400

Doel vak
During this course you will get acquainted with the most often used stochastic models and how they are applied in practice. The emphasis is on the variety of stochastic models (and their analysis) that appear in practice, rather than an in-depth study of a single-class of models. During the course you learn to handle such practically motivated problems as an independent researcher; this means that you:
- learn to determine the appropriate model
- are able to formulate the problem mathematically correct
- are able to solve the stochastic model
- know how to interpret the outcome.

Inhoud vak
This course deals with a number of stochastic modeling techniques that are often used in practice. They are motivated by showing the business context in which they are used. Topics we deal with are: time-dependent Poisson processes and infinite-server queues, renewal processes and simulation, birth-death-processes, basic queueing models, and inventory models. We also repeat and extend certain parts of probability theory.

Onderwijsvorm
Lecture and instruction.

Toetsvorm
Written examination and two hand-in assignments (one in each period).

Literatuur
Lecture notes of Ger Koole (made available via Canvas).
Recommended: H.C. Tijms, A First Course in Stochastic Models, 2003. This is available as e-book via the VU library (ubvu), free of charge.
Additional material will be announced in due time.

Aanbevolen voorkennis
Probability theory, Poisson process, Markov chains in continuous time

Doelgroep
mBA, mMath

Business Process Analytics

Vakcode	X_400650 ()
Periode	Periode 4
Credits	6.0
Voertaal	Engels
Faculteit	Faculteit der Exacte Wetenschappen
Coördinator	dr. H. Leopold MSc
Examinator	dr. H. Leopold MSc
Docent(en)	dr. H. Leopold MSc
Lesmethode(n)	Hoorcollege, Practicum
Niveau	400

Doel vak
After taking this course, the student will:

- be aware of the current possibilities to support BPM with information technology.
- understand and be able to employ process mining techniques for the purpose of process discovery, compliance checking, and improvement.
- know key technologies for analyzing large process model repositories.
- know and be able to employ basic as well as advanced NLP techniques for the purpose of process analysis.
- know and be able to use process model simulation for testing and improving process design.

Inhoud vak
There is a steadily increasing interest of organizations to use Business Process Management (BPM) for documenting and improving their operations. However, the associated manual effort for thoroughly eliciting, documenting, and updating process knowledge in the form of process models is often considerable.

Within this course, we put an emphasis on the technological and analytical perspective and discuss how they can support organizations in effectively and efficiently implementing BPM. In fact, techniques from the fields of information retrieval, data mining as well as simulation provide valuable foundations to reduce to the manual effort in the context of BPM. Hence, we introduce and discuss four different technological angles and demonstrate how each of these angles can strengthen the different phases of the BPM life cycle. In particular, we address the following technological areas:

1. Process Mining: The technology of process mining builds on the analysis of event logs that were generated by information or workflow systems. We discuss how process mining techniques can be used for process discovery, compliance checking, and improvement and elaborate on basic as well as advanced process mining algorithms. In addition, we introduce current process mining tools for the application of process

mining in practice.

2. Process Model Collections: Many large organizations maintain process model repositories with several hundred process models. Hence, manual analysis efforts are time-consuming and cumbersome. Recognizing this, we introduce key concepts to automatically analyze process model collections. Among others, we discuss techniques for process model comparison, process model search, and behavioral analysis of process models.

3. Natural Language Analysis: The automated analysis of natural language, which is referred to as Natural Language Processing (NLP), has been applied in many contexts. As an example, consider Apple's Siri or Google's S Voice, which are capable of interpreting human speech. In fact, also organizations and their business processes may considerably benefit from natural language processing techniques. Hence, we introduce the key NLP techniques that are relevant in the context of BPM. Among others, we discuss techniques for process model content analysis, process model quality insurance, and identification of improvement potential in process models.

4. Simulation: The simulation of business processes is a tool that is used to predict performance and to understand the impact of change. It, for instance, allows organizations to test processes before they are actually technically implemented in a system. Due to its usefulness for organizations, we introduce the technological foundations for process simulation and give an overview of process simulation tools.

The various lectures and instructions will be devoted to these technological areas.

Onderwijsvorm
There will be lectures as well as work instructions.

Toetsvorm
The grading for students who follow this course in the scheduled period will be based on two grades:

1. The first grade is based on a number of home assignments. The goal of the assignments is to evaluate whether the students can successfully apply the content from the lecture. Among others, the students will be asked to mine a business process model from a given event log and to automatically infer relevant information using natural language processing tools from a given text.

2. The second grade is gained by participating in the regular exam during the exam week. The exam is a closed book exam, which consists of theoretical questions and small assignments. Selected chapters from the books "Fundamentals of Business Process Management", "Process Mining", and "Speech and Language Processing" will be the basis for this exam.

The overall result for this exam is the rounded, weighted average of the first grade (50%) and the second grade (50%) provided that both grades (unrounded) at least amount to a 5.00. If either of the grades is lower than a 5.00, the overall grade for this course is determined by the rounded, lowest grade of the two.

For all students who fail the course in the scheduled period or decide to follow the course outside this period, the course is graded solely by

the grade for the re-exam. This is a full exam similar to the original exam and the assignments. The re-exam is a closed book exam, too.

Literatuur
1. Fundamentals of Business Process Management. Dumas, M., La Rosa, M., Mendling, J., Reijers, H.A. Springer, 2013. ISBN: 978-3-642-33142-8 (Print) 978-3-642-33143-5 (Online).

2. Process Mining. Discovery, Conformance and Enhancement of Business Processes. van der Aalst, Wil. Springer, 2011. ISBN: 978-3642193446.

3. Speech and Language Processing, Jurafsky, Dan, Martin, James H. Pearson International Edition, 2008. ISBN: 978-0135041963.

Aanbevolen voorkennis
Students will, among others, benefit from the knowledge they acquired in the courses Information Management and Business Process Management. Motivated students, however, will be able to master the course without prior knowledge from these courses.

Doelgroep
This is an interdisciplinary course. Any student who is interested in learning how technology can be used to improve business processes in practice is invited to join this course.

Computational Finance

Vakcode	XMU_418045 ()
Periode	Periode 4
Credits	6.0
Voertaal	Engels
Faculteit	Faculteit der Exacte Wetenschappen
Lesmethode(n)	Hoorcollege
Niveau	400

Inhoud vak
http://studiegids.uva.nl/xmlpages/page/2017-2018/zoek-vak/vak/32277

Doelgroep
mSFM

Overige informatie
This course is offered at the UvA. For more information contact: FNWI Education Service Centre, Science Park 904, servicedesk-esc-science@uva.nl, +31 (0)20 525 7100.
Enrolment via https://m.sis.uva.nl/vakaanmelden is required.

Computational Intelligence

Vakcode	XM_417015 ()
Periode	Periode 2
Credits	6.0
Voertaal	Engels
Faculteit	Faculteit der Exacte Wetenschappen

Coördinator	dr. M. Hoogendoorn
Examinator	dr. M. Hoogendoorn
Lesmethode(n)	Hoorcollege, Computerpracticum
Niveau	400

Doel vak
The overall aim of this course is to provide knowledge about concepts, theory, and techniques used in computational intelligence and the know-how to employ these for making intelligent machines. In particular, to enable students to:
- gain profound understanding of fundamental computational intelligence concepts, algorithms, and their implementation;
- understand the theoretical background of proposed solutions;
- develop skills in the use of computational intelligence and to demonstrate this in physical robots or virtual creatures;
- appreciate relevant current research topics in the theory and practice of computational intelligence.

Inhoud vak
Computational intelligence can be positioned as the research area that follows a bottom-up approach to developing systems that exhibit intelligent behavior in complex environments. It is often contrasted to the top-down approach followed by traditional artificial intelligence. Typically, sub-symbolic and nature-inspired methods are adopted that tolerate incomplete, imprecise and uncertain knowledge. As a consequence, the resulting approaches allow for approximate, manageable, robust and resource-efcient solutions.

This course covers nature-inspired techniques such as neural networks, evolutionary algorithms and swarm intelligence. Special attention is paid to using such techniques for making autonomous and adaptive machines.

Onderwijsvorm
Lectures
Presentation/symposium
Working independently on the project
Supervision/feedback meeting

Toetsvorm
Average of written exam (50%) and a programming assignment (50%). Both sub-grades must be sufficient.

Literatuur
Literature: Slides and scientific papers
Other: Additional papers will be made available.

Continuous Optimization

Vakcode	X_400446 (400446)
Periode	Periode 1+2
Credits	6.0
Voertaal	Engels
Faculteit	Faculteit der Exacte Wetenschappen
Coördinator	dr. R. Bekker

Examinator	dr. R. Bekker
Niveau	400

Inhoud vak
This course is part of the Joint National Master Programme in Mathematics.
For schedules, course locations and course descriptions see https://elo.mastermath.nl/

Doelgroep
mMath; mBA

Intekenprocedure
You have to register your participation in each Mastermath course via https://elo.mastermath.nl/login
Registration is mandatory and absolutely necessary for transferring your grades from Mastermath to the administration of your university.

Data Mining Techniques

Vakcode	X_400108 (400108)
Periode	Periode 5
Credits	6.0
Voertaal	Engels
Faculteit	Faculteit der Exacte Wetenschappen
Coördinator	dr. M. Hoogendoorn
Examinator	dr. M. Hoogendoorn
Docent(en)	dr. M. Hoogendoorn
Lesmethode(n)	Hoorcollege
Niveau	500

Doel vak
The aim of the course is that students acquire data mining knowledge and skills that they can apply in a business environment. How the aims are to be achieved: Students will acquire knowledge and skills mainly through the following: an overview of the most common data mining algorithms and techniques (in lectures), a survey of typical and interesting data mining applications, and practical assignments to gain "hands on" experience. The application of skills in a business environment will be simulated through various assignments of the course.

Inhoud vak
The course will provide a survey of basic data mining techniques and their applications for solving real life problems. After a general introduction to Data Mining we will discuss some "classical" algorithms like Naive Bayes, Decision Trees, Association Rules, etc., and some recently discovered methods such as boosting, Support Vector Machines, and co-learning. A number of successful applications of data mining will also be discussed: marketing, fraud detection, text and Web mining, possibly bioinformatics. In addition to lectures, there will be an extensive practical part, where students will experiment with various data mining algorithms and data sets. The grade for the course will be based on these practical assignments (i.e., there will be no final examination).

Onderwijsvorm
Lectures (h) and compulsory practical work (pra). Lectures are planned to be interactive: there will be small questions, one-minute discussions, etc.

Toetsvorm
Practical assignments (i.e. there is no exam). There will be two assignments done in groups of three. There is a possibility to get a grade without doing these assignments: to do a real research project instead (which will most likely to involve more work, but it can also be more rewarding). For the regular assignments the first assignment counts for 40% and the second for 60%. The grade of both assignments needs to be sufficient to pass the course.

Literatuur
Ian H. Witten, Eibe Frank, Mark A. Hall, Data Mining: Practical Machine Learning Tools and Techniques (Third Edition). Morgan Kaufmann, January 2011
ISBN 978-0-12-374856-0

Aanbevolen voorkennis
Kansrekening and Statistiek or Algemene Statistiek (knowledge of statistics and probabilities) or equivalent. Recommended: Machine Learning.

Doelgroep
mBA, mCS, mAI, mBio

Distributed Systems

Vakcode	X_400130 (400130)
Periode	Periode 2
Credits	6.0
Voertaal	Engels
Faculteit	Faculteit der Exacte Wetenschappen
Coördinator	dr. A. Uta MSc
Examinator	prof. dr. ir. A. Iosup
Docent(en)	prof. dr. ir. A. Iosup
Lesmethode(n)	Hoorcollege, Werkcollege
Niveau	400

Doel vak
After taking this course, students will be able to:
1. Explain the basic concepts, objectives, and functions of distributed computing systems, e.g., communication, resource management and scheduling, data consistency, fault-tolerance, performance.
2. Compare distributed computing with other computing paradigms (i.e., centralized, parallel).
3. Identify the different flavors of modern distributed systems (i.e., peer-to-peer systems, cluster computing, grid computing, cloud computing, datacenters, distributed HPC, SDN, Big Data systems, IoT systems).
4. Analyze the trade-offs inherent in the design of modern distributed systems.

5. Design your portfolio distributed-system, with many basic and some complex operations of modern distributed systems.
6. Implement your portfolio distributed-system.
7. Analyze your portfolio distributed-system.

Inhoud vak
This course focuses on distributed computing systems. In general, debugging and tuning existing systems, and designing, implementing, and analyzing new distributed computing systems remains vital and challenging.

Starting with the mid-1990s, computing is undergoing a revolution, in which collections of independent computers appear to users as a single, albeit distributed, computing system. Motivated by the advent of the Internet, by the increase in the computation capacity of consumer computers, by the commoditization of server-grade machines, by energy constraints, etc., the distributed computing paradigm has permeated all fields using computers. Current distributed computing applications range from social networks to banking, from peer-to-peer file-sharing to high-performance computing used in research, from massively multiplayer online games to business-critical workloads, etc. Important advances have helped to fuse heterogeneous resources into truly global distributed systems, for example in scientific computing, where distributed computation is using Big Data and distributed sensors to produce meaningful progress for the humankind. We will focus in this course on a number of these modern examples of distributed computing systems.

Although so many distributed systems already exist, the list of conceptual and technical challenges they pose is long. Depending on requirements, even trivial communication between nodes of the distributed system can be challenging. The failure of a single node, or sometimes even a performance hiccup, can bring an entire system down; with it, other nodes or entire other systems may also crash, experiencing correlated and catastrophic failures. Data consistency and coordinating nodes remain important challenges made worse by the large-scale of real-world deployments. Poor resource management and naive scheduling can lead to orders-of-magnitude higher operational costs and consumption of energy that we simply cannot spare. It is not uncommon for a modern distributed system to quickly rise and then fall in popularity, as exemplified by the 2016 example of Pokemon Go. We will present in this course real-world situations where modern distributed systems have behaved poorly.

Addressing these challenges requires unique approaches and concepts. Separating concerns and breaking down problems into smaller cases often lead to limited success, because many properties of distributed systems can only be achieved end-to-end. Can anyone imagine a perfectly reliable production pipeline, if even one of its key stages can suffer failures? Building capability by adding resources is often offset by the distributed nature of the system. Can anyone ignore the physical limitations of communication around the globe? In this course, we will focus on the unique approaches and principles of distributed systems, from specific architectures and communication protocols, to specific concepts in resource management and scheduling, data consistency, fault-tolerance, and performance.

Onderwijsvorm

The course is taught as a series of lectures, in combination with self-study and with a large practical assignment.

Toetsvorm
Written exam. Depending on enrollment, an oral exam may also be available.
Report on the practical assignment.

Literatuur
The course uses as textbook the book:
Maarten van Steen and Andrew S. Tanenbaum, Distributed Systems, 3rd. Ed., online edition, 2017. (free for all) [Online] Available: https://www.distributed-systems.net/index.php/books/distributed-systems-

The lecture slides also recommend additional literature. The study guide available on Canvas also indicates other worthwhile sources of information.

Vereiste voorkennis
Ability to work in teams for the practical assignment.
Ability to develop code using modern software engineering practices, e.g., setting up your own GitHub repository, co-editing using tools such as Overleaf or Sharelatex, etc., is a big plus.

Aanbevolen voorkennis
Students should have taken standard courses on:
- Computer networks.
- Programming paradigms, in particular OOP and/or actor-based approaches.
- Software engineering.
Prior experience with Internet, web, distributed, or parallel programming is helpful.
Prior experience with operating systems development and analysis, and in general experience with computer systems courses, is a big plus.

Doelgroep
mCS, mPDCS, mSNE (UvA)

Overige informatie
This course uses gamification.

Dual Workperiod

Vakcode	XM_41010 ()
Periode	Ac. Jaar (september)
Credits	12.0
Voertaal	Engels
Faculteit	Faculteit der Exacte Wetenschappen
Coördinator	drs. H.J.M. van Goor-Balk
Docent(en)	drs. H.J.M. van Goor-Balk
Lesmethode(n)	Hoorcollege
Niveau	500

Doel vak

During the dual work period the student gains experience and skills. The dual period allows the student to bring the learning into practice. So the student can apply his/her theoretical knowledge into practice. The student also brings practical work experience back to the university. In addition, the student will receive relevant work experience while studying and can already develop (soft) skills which are of great value after graduation. As a result the student is easier to deploy in the labor market after graduation.

Inhoud vak
During sixteen months, students are required to divide their time equally between work and study. So study and work are fully integrated. The student is an employee and a student at the same time. The student is on the payroll of the host organization for 20-24 hours a week during 16 months. The student will conduct work which is of direct relevance to the master's programme Business Analytics.

Onderwijsvorm
During the dual master’s Business Analytics:
- The student is employed by the host company on a fixed-term contract and are therefore officially on that company's payroll.
- The student's working activities will be closely involved with the host organization's primary business processes.
- The student will often be required to work with others in a team setting, whereby it may not be possible to identify clearly your own contribution or the products for which you are (individually) responsible.
- The student's work period is of fixed duration.
- The assessment takes specific and significant account of the student's performance during the work period.

Toetsvorm
You are required to produce a written report of your activities during the work period, and to give a presentation at the Vrije Universiteit Amsterdam in December 2018 of January 2019. The report will describe the activities you have undertaken and should clearly demonstrate an understanding of the structure of the organization.

The dual master’s Business Analytics coordinator will, in consultation with a member of the internship committee Business Analytics, and the external supervisor, give an overall assessment of the work period. This assessment will take into account:
- The level of the required activities: the final report and the presentation.
- The level and the manner in which the required activities were performed: the assessment forms to be completed by the external supervisor and the meeting halfway through the dual work period.

Doelgroep
mBA-D

Intekenprocedure
Admission to the dual master’s program is granted to those who have a Business Analytics Bachelor's degree. For those with another university Bachelor's degree, such as Mathematics, Econometrics, Computer Science, or a Bachelor's degree from an institute of higher education, admission may be granted on an individual basis. Those seeking admission to the dual master’s program should realize that admission also depends on obtaining suitable employment. The Vrije Universiteit Amsterdam has

contacts with a number of companies that are interested in participating in this program.

The formal approval of the Business Analytics Internship Committee is required before the student can actually take up employment.

A VUnet registration for this course automatically gives access to the corresponding Canvas site. If you want to apply for a dual work place, but you cannot enroll on VUnet for the Dual Workperiod, you can already find some information on http://tinyurl.com/duaal-ba-studeren.

Overige informatie
For more information on the dual program:
- http://tinyurl.com/duaal-ba-studeren

Entrepreneurship in Data Science and Analytics

Vakcode	X_405122 ()
Periode	Periode 4+5
Credits	6.0
Voertaal	Engels
Faculteit	Faculteit der Exacte Wetenschappen
Coördinator	prof. dr. G.M. Koole
Examinator	prof. dr. G.M. Koole
Docent(en)	prof. dr. J.F.M. Feldberg, prof. dr. E. Masurel, prof. dr. G.M. Koole
Lesmethode(n)	Hoorcollege, Werkcollege, Deeltoets extra zaalcapaciteit
Niveau	400

Doel vak
The objective of this course is to learn about entrepreneurship, with a focus on IT, and especially business ideas that involve Data Science and/or Analytics.

Inhoud vak
This course consists of several elements:
- lectures about different aspects of entrepreneurship;
- guest lectures by for example successful entrepreneurs and investors in starting companies;
- writing a business plan for a real or imaginary company.
For students who have the intention to start their own company we will make it possible to pitch their ideas for venture capitalists (like a Dragons's Den).
Presence during the lectures is compulsory.
The course will be given by Enno Masurel (specialized in Entrepreneurship, FEWEB) and Ger Koole (Analytics, FEW), assuring that all aspects of IT entrepreneurship will be covered.

Onderwijsvorm
weekly lectures

Toetsvorm
The assessment consists of:
- a written exam
- the writing of a business plan (business model canvas)

Literatuur
handouts to be distributed during the course

Doelgroep
mBA, mMath, mCS, mAI, mIS, mPDCS

Overige informatie
Register as usual and via Canvas

Evolutionary Computing

Vakcode	X_400111 (400111)
Periode	Periode 1
Credits	6.0
Voertaal	Engels
Faculteit	Faculteit der Exacte Wetenschappen
Coördinator	J.V. Heinerman MSc
Examinator	J.V. Heinerman MSc
Docent(en)	prof. dr. A.E. Eiben, J.V. Heinerman MSc
Lesmethode(n)	Hoorcollege
Niveau	400

Doel vak
This course has a threefold objective: 1) To learn about computational methods based on Darwinian principles of evolution. 2) To illustrate the usage of such methods as problem solvers and as simulation tools. 3) To gain hands-on experience in performing computational experiments with evolutionary algorithms.

Inhoud vak
The course is treating various algorithms based on the Darwinian evolution theory. Driven by natural selection (survival of the fittest), an evolution process is being emulated and solutions for a given problem are being "bred". During this course all "dialects" within evolutionary computing are treated (genetic algorithms, evolution strategies, evolutionary programming, genetic programming). Applications in optimisation, constraint handling,
machine learning, and robotics are discussed. Specific subjects handled include: various genetic structures (representations), selection techniques,
sexual and asexual variation operators, (self-)adaptivity. Special attention is paid to methodological aspects, such as algorithm design and tuning. If time permits, subjects in Artificial Life will be handled. Hands-on- experience is gained by a compulsory programming assignment.

Onderwijsvorm
Oral lectures and compulsory Java programming assignment (in teams of 3). Highly motivated students can replace the programming assignment by a special research track under the personal supervision of the lecturer(s). These research projects aim at publications.

Toetsvorm

Written exam and programming assignment (weighted average). To pass the course as a whole, you must pass both the exam and the programming assignment.

Literatuur
Eiben, A.E., Smith, J.E., Introduction to Evolutionary Computing. Springer, 2015, 2nd edition, ISBN 978-3-662-44873-1.

Vereiste voorkennis
Java programming skills are necessary to do the practical assignment.

Doelgroep
mBA, mAI, mCS, mPDCS

Financial Markets and Institutions

Vakcode	E_EBE3_FMI ()
Periode	Periode 4
Credits	6.0
Voertaal	Engels
Faculteit	School of Business and Economics
Coördinator	dr. J. Wrampelmeyer
Examinator	dr. J. Wrampelmeyer
Lesmethode(n)	Hoorcollege, Werkcollege, Instructiecollege
Niveau	300

Doel vak
In the course students develop a deep understanding of financial markets, bank supervision and central banking (Academic skills, Knowledge). You learn to analyze real-life applications such as recent central bank and regulatory policies using the concepts from the literature (Bridging theory and practice). You solve problem sets (Quantitative skills) and form teams to work on case studies (Research skills).

After the course, you can:
- explain how financial markets and institutions affect everyday life as well as how they create value and why this is the case;
- state stylized facts of the term structure of interest rates;
- describe the structure of the banking sector and banking supervision;
- explain the main risks involved in banking and the most important tools to manage these risk;
- explain the need for regulation of the financial system;
- describe approaches to managing systemic risk and recent developments in the regulatory framework;
- define the principles of monetary policy;
- interpret decisions by central banks on monetary policy and how they affect the financial system and the real economy.

Inhoud vak
Financial markets are playing an important role in a modern economy. This course gives students an overview on how the financial system operates and where its weaknesses lie. It is an important building block for understanding our economy and students can connect micro and macro theories to the concepts developed in this course. The course also

provides the necessary background for a future career in a policy environment or financial institution.

Onderwijsvorm
Lectures.
Tutorials.

Toetsvorm
Written exam – Individual assessment.
Interim Assignments – Group assessment.

Literatuur
- Mishkin, Matthews and Guiliodori (2013) Economics of Money, Banking and Financial Markets: European edition, 1st European edition, Pearson. ISBN 978-0273731801
- Additional readings will be announced on Canvas.

Vereiste voorkennis
Finance I or equivalent.

Aanbevolen voorkennis
Finance I, Finance II and Corporate Finance.

Overige informatie
It is not allowed to follow this course if you already earned credits (ECs) for the course Finance, Banking & Insurance from the old curriculum.

Financial Modelling and Derivatives

Vakcode	E_IBK3_FMD ()
Periode	Periode 4
Credits	6.0
Voertaal	Engels
Faculteit	School of Business and Economics
Coördinator	dr. T.C. Dyakov
Examinator	dr. T.C. Dyakov
Lesmethode(n)	Hoorcollege, Werkcollege, Instructiecollege
Niveau	300

Doel vak
In this course you will learn about financial modelling of risk and financial derivatives.

In the financial modelling module, the central concept is the relationship between risk and return on financial assets (Knowledge). The goal of this part of the course is to gain insight into the risk associated with financial portfolios and investments and to be able to calculate/estimate such risk on the basis of historical data. Furthermore, other goal is to learn how to construct portfolios on the basis of mean-variance optimization and how to benefit from diversification possibilities. Finally, another goal is to learn how to compute expected returns on investments on the basis of the Capital Asset Pricing Model and multifactor models (Quantitative skills).

In the derivatives module, the goal is to gain insight into various financial derivatives such as futures and options, their properties, valuation and risks associated with them (Knowledge). Another goal is to learn how these derivatives can be used to hedge financial risks (Quantitative skills).

Upon accomplishing these goals, you will gain new academic, research and quantitative skills, as well as develop your professional knowledge in the area of financial risk and derivatives. Furthermore, by illustrating the concepts with examples of portfolios, investments and hedging problems provided by financial institutions, we will bridge the gap between theory and practice, enabling you to translate theoretical concepts into practical applications (Link to practice).

Inhoud vak
Central topics in financial modeling that will be discussed are:
- measures of risk in financial markets: variance and volatility of returns;
- trade-off between risk and return;
- estimation of average return and volatility;
- concepts of covariance and correlation; their estimation;
- risk and return of portfolios;
- diversification;
- universal risk measures: Value-at-Risk and Expected Shortfall;
- concept of efficient portfolio. Markowitz model;
- CAPM;
- risk premium and beta;
- multifactor models of risk.

Central topics in the part on derivatives that will be discussed are:
- types and characteristics of financial derivatives;
- use of derivatives in risk hedging;
- options: determining option price with the help of the binomial tree;
- sensitivities of options (Greeks);
- Black-Scholes model for option pricing and its assumptions;
- delta hedging of options;
- implied volatilities and volatility smiles;

Onderwijsvorm
Lectures.
Tutorials.

Toetsvorm
Written midterm test, written exam and computer assignment.

Literatuur
J. Berk and P. DeMarzo (2013), Corporate Finance, Pearson, 3rd Global Edition, ISBN 9781783990320, chapters 10-13, 20-22 and 30).

Aanbevolen voorkennis
Finance I and Quantitative Research Methods I and II.

Heuristic Methods in Operations Research

Vakcode	X_418006 (418006)
Periode	Periode 1+2
Credits	6.0

Voertaal	Engels
Faculteit	Faculteit der Exacte Wetenschappen
Coördinator	dr. R. Bekker
Examinator	dr. R. Bekker
Niveau	400

Inhoud vak
This course is part of the Joint National Master Programme in Mathematics.
For schedules, course locations and course descriptions see https://elo.mastermath.nl/

Doelgroep
mMath, mBA

Intekenprocedure
You have to register your participation in each Mastermath course via https://elo.mastermath.nl/
Registration is mandatory and absolutely necessary for transferring your grades from Mastermath to the administration of your univesity.

International Financial Management

Vakcode	E_IBK3_IFM ()
Periode	Periode 5
Credits	6.0
Voertaal	Engels
Faculteit	School of Business and Economics
Coördinator	dr. K.L. Wolk
Examinator	dr. K.L. Wolk
Lesmethode(n)	Hoorcollege, Werkcollege, Instructiecollege
Niveau	300

Doel vak
The objective of the course is to acquaint students with the developments in international financial markets from a perspective of managerial decision making. The course is designed to provide future's financial managers with an understanding of the fundamental concepts and the tools necessary to be effective global managers. The aim is to provide students with an understanding of these concepts and techniques used in risk management. (Knowledge, Quantitative Skills) The students will develop skills in reading and understanding academic papers as well as critical thinking on economic events with a focus on the financial aspects of managerial decisions. (Research Skills, Bridging Theory and Practice) They are encouraged to improve analytical thinking abilities, to think beyond the boundaries of economics and finance theories. (Academic Skills, Broadening your Horizon)

Inhoud vak
During the course, we will mainly discuss the structure of financial markets (foreign exchange, fixed income and equity markets) and explore the issues that are encountered by multinational enterprises, with an emphasis on risk management. When having completed this course, students

will have a clear understanding how financial markets work and how the multinational firm interacts with other market participants. In particular, students will:
- understand the development of the international monetary system and other financial institutions,
- be acquainted with different financial instruments used to manage foreign exchange rate risk (forwards, futures, options)
- be acquainted with the specifics of various financial markets (money, bond, equity)
- learn how to manage foreign exchange risk and interest risk in a multinational firm.

Onderwijsvorm
-Lectures
-Tutorials

Toetsvorm
Written exam – Individual assessment
(Interim) Assignment(s) – Individual assessment

Literatuur
1. Eun & Resnick: International Finance, Global Edition (ISBN: 9780077161613)
2. Additional articles and/or cases (announced at the start of the course)

Aanbevolen voorkennis
BK:
2.2 Finance; 3.4 Financial Modelling and Derivatives; 2.5 Finance II

IBA:
2.2 Finance; 2.5 Corporate Finance in Emerging Economies; 3.4 Financial Modelling and Derivatives

Investments

Vakcode	E_EBE3_INVES ()
Periode	Periode 5
Credits	6.0
Voertaal	Engels
Faculteit	School of Business and Economics
Coördinator	dr. T.C. Dyakov
Examinator	dr. T.C. Dyakov
Lesmethode(n)	Hoorcollege, Werkcollege
Niveau	300

Doel vak
This course offers a comprehensive introduction to the world of investments. The course is structured in four broad parts, covering fundamental areas of investments: Part 1. Portfolio theory and asset pricing; Part 2. Empirical evidence on security returns and portfolio management; Part 3. Fixed-income securities; Part 4. Options, futures and other derivatives. All four parts of the course are closely knitted to the learning goals of Academic Skills, Research Skills, Quantitative Skills, Knowledge and Bridging Theory and Practice.

By the end of the course you should be able to:
- compute fundamental risk-management techniques: Value-at-Risk and Expected Shortfall;
- apply the Markowitz portfolio selection model and construct an efficient frontier of risky assets;
- compare the Capital Asset Pricing Model (CAPM) against the Arbitrage Pricing Theory. Test the predictions of the CAPM;
- price fixed income securities and construct the Term Structure of Interest Rate;
- solve portfolio immunization problems by matching the duration of assets and liabilities;
- build a binomial tree and apply the Black-Scholes formula.

Inhoud vak
Investment decisions take a prominent role in everyday life. We can think of investment decisions taken by institutional investors (banks, insurance companies, pension funds, mutual funds), but also of financial decisions taken by individual households (additional pension savings, savings for children education, buying a house, etc.). Investment theory is also strongly linked to risk management. The importance of sound decision making in this field has been underlined by recent experiences on financial markets, law suits involving complex financial products for retail clients, etc. The key objective of this course is to provide understanding of the pricing of different asset classes and insights into the principles of investment analysis. A framework is developed that allows one to address a variety of (at first sight) completely different investment problems in a unified way.

Onderwijsvorm
Lectures.
Tutorials.

Toetsvorm
Written exam – individual assessment.
(Interim) Assignment(s) – group assessment.

Literatuur
Zvi Bodie, Alex Kane and Alan J. Marcus: Investments, McGraw Hill (10th Global Edition).
Additional readings might be announced on Canvas.

(Literature has been adjusted at 26-03-2018)

Vereiste voorkennis
Finance I or equivalent.

Aanbevolen voorkennis
The course relies on prior knowledge on linear algebra and statistics (QRM I, QRM II, and QRM III). Even though it offers a very brief introduction to the concepts and tools in this area that we will primarily use, students are strongly advised to review this material from relevant courses in the first two years of studies. I will further assume that students have a good understanding of the material covered in Finance I, Finance II, and Financial Markets and Institutions.

Students are also recommended to refresh their basic Excel and STATA skills, as weekly empirical assignments constitute an important part of the course.

Overige informatie
This course provides the knowledge basis for students aiming at an MSc in Finance and a career in the financial sector.

Machine Learning 1

Vakcode	XMU_418144 ()
Periode	Periode 1
Credits	6.0
Voertaal	Engels
Faculteit	Faculteit der Exacte Wetenschappen
Lesmethode(n)	Hoorcollege

Inhoud vak
http://studiegids.uva.nl/xmlpages/page/2017-2018/zoek-vak/vak/31203

Overige informatie
This course is offered at the UvA. For more information contact: FNWI Education Service Centre, Science Park 904, servicedesk-esc-science@uva.nl, +31 (0)20 525 7100.
Enrolment via https://m.sis.uva.nl/vakaanmelden is required.
For courses taught in period 1 and period 2, enrolment via https://datanose.nl/#specialenrol is required.

Master Project Business Analytics

Vakcode	X_400459 (400459)
Periode	Ac. Jaar (september)
Credits	36.0
Voertaal	Engels
Faculteit	Faculteit der Exacte Wetenschappen
Coördinator	drs. H.J.M. van Goor-Balk
Examinator	drs. H.J.M. van Goor-Balk
Lesmethode(n)	Hoorcollege
Niveau	600

Doel vak
The objectives of the Master Project Business Analytics are:
- To research and analyse a specific issue or problem affecting the host organization, and to suggest (potential) solutions.
- To present the results of that research in an appropriately academic manner. This requirement also applies to the verbal presentation.
- To complete the Master Project Business Analytics within the allotted period (to include all required research activities).

Besides the main objectives the other obejctives are:
- To gain an understanding of the way in which the organization functions. The student will gain a general impression how the organization as a whole works, including its primary business processes and its support processes. The internship should be positioned within these processes.
- To practise and develop social and communication skills. The student

is introduced to the standards and values in place within the host organization. He/she will develop communication skills through personal interaction with the staff of the organization, and through the written and verbal reports.
- To explore potential career options.

Inhoud vak
Each Master's programme is concluded by an external master project. This is in principle a project to be carried out within a business, industry or research facility other than the departments of Mathematics and Computer Science.

Onderwijsvorm
The student is an intern of the host organization. The student will be supervised by two staff members of the Faculty of Science.

Toetsvorm
A written report and a verbal presentation.

Literatuur
Assigned individually

Vereiste voorkennis
At least 78 credits, and the Research Paper Business Analytics.

Doelgroep
mBA, mBA-D

Intekenprocedure
You have to enroll yourself for this Master Project Business Analytics via VUnet. If you are planning to start your Master Project Business Analytics within four months and you cannot enroll for the Master Project because you do not meet the requirements yet, please contact Annemieke van Goor (H.J.M.van.Goor-Balk@vu.nl) so she can give you access to the Master Project Business Analytics on Canvas. Here you find the information you need about the Master Project Business Analytics.

Mathematical Systems and Control Theory

Vakcode	X_400180 ()
Periode	Periode 1+2
Credits	6.0
Voertaal	Engels
Faculteit	Faculteit der Exacte Wetenschappen
Coördinator	prof. dr. A.C.M. Ran
Examinator	prof. dr. A.C.M. Ran
Docent(en)	prof. dr. A.C.M. Ran
Lesmethode(n)	Hoorcollege, Werkcollege
Niveau	400

Doel vak
The course aims to introduce the student to the mathematical theory of control systems.

Inhoud vak
Many phenomena are characterized by dynamic behaviour where we are interested in a certain input/output behaviour. Examples are to be found in the exact and natural sciences (mechanics, biology, ecology), in engineering (air- and spacecraft design, mechanical engineering) as well as in economics and econometrics (macro- economical models, trend and seasonal influences in demand and supply, production systems). Systems theory is concerned with modeling, estimation and control of dynamical phenomena. During the course the following subjects will be treated: models and representations (linear systems, input-output, state space, transfer function, stochastic systems, spectrum), control (stabilisation, feedback, pole placement, dynamic programming, the LQ problem), and identification and prediction (parameter estimation, spectral analysis, Kalman- filter, model reduction). Applications are in the area of optimal control and prediction.

Onderwijsvorm
There is a lecture of two hours each week. In addition, there is another session which will be half lecture and half practicum, in which there is the possibility to ask questions about the compulsary computerpracticum. The practicum makes use of the Matlab package.

Toetsvorm
The computerpracticum counts for 50%, the oral examination concerns the theory and counts for 50%.

Literatuur
Chr. Heij, A.C.M. Ran and F. van Schagen, Introduction to Mathematical Systems Theory, Birkhauser Verlag.

Aanbevolen voorkennis
Analysis, probability theory, statistics.
Complex analysis and Fourier theory would be useful, but are not absolutely necessary.

Doelgroep
3W, mBA, mMath

Optimization of Business Processes

Vakcode	X_400422 (400422)
Periode	Periode 4+5
Credits	6.0
Voertaal	Engels
Faculteit	Faculteit der Exacte Wetenschappen
Coördinator	prof. dr. G.M. Koole
Examinator	prof. dr. G.M. Koole
Docent(en)	prof. dr. G.M. Koole
Lesmethode(n)	Hoorcollege
Niveau	400

Doel vak
To learn about applications of stochastic operations research in the context of a number of important application areas, especially manufacturing and services.

Inhoud vak
We deal with a number of application areas of stochastic modeling: production logistics, call centers, health care and revenue management. For each area we present quantitative problems and discuss how they can be solved using mathematical models. We also discuss a number of new models. Several guest lectures are given by people from industry.

Onderwijsvorm
Lectures and practical work.

Toetsvorm
Written examination, individual assignments, and a book presentation.

Literatuur
Lecture notes.

Aanbevolen voorkennis
Applied Stochastic Modeling or equivalent knowledge

Doelgroep
mBA, mBA-D, mMath

Overige informatie
Attendance mandatory.

Performance of Networked Systems

Vakcode	X_405105 ()
Periode	Periode 4
Credits	6.0
Voertaal	Engels
Faculteit	Faculteit der Exacte Wetenschappen
Coördinator	prof. dr. R.D. van der Mei
Examinator	prof. dr. R.D. van der Mei
Docent(en)	dr. ing. T. Kielmann, prof. dr. R.D. van der Mei
Lesmethode(n)	Hoorcollege
Niveau	400

Doel vak
Students will acquire basic knowledge of:
• performance aspects of networked systems, consisting of servers, services, and clients
• performance engineering principles and methods,
• quantitative models for predicting and optimizing the performance of networked systems,
• quantitative models for planning capacity of networked systems.
Students will gain experience in engineering and planning performance of networked systems, and will learn how to tackle practical performance problems arising in the ICT industry.

Inhoud vak
Over the past few decades, information and communication technology (ICT) has become ubiquitous and globally interconnected. As a consequence, our information and communication systems are expected to

process huge amounts of (digital) information, which puts a tremendous burden on our ICT infrastructure. At the same time, our modern society has become largely dependent on the well-functioning of our ICT systems; large-scale system failures and perceivable Quality of Service (QoS) degradation may completely disrupt our daily lives and have huge impact on our economy.

Motivated by this, the course will focus on performance-related issues of networked systems. In the first part, we study capacity planning and modeling for server systems and networks. In the second part, we study the client side of performance while focusing on web applications for both desktop and mobile devices. We address questions like:

- How can we design and engineer networked systems for performance?
- How can we plan server capacity in networked systems?
- How can web applications improve performance across wired and wireless networks?

Onderwijsvorm
Classroom lectures and practical homework assignments.

Toetsvorm
The assessment will be based on both homework assignments and a written exam.

Literatuur
Textbook, supplemented with a reader on Stochastic Performance Modelling.

High Performance Browser Networking, Ilya Grigorik, O-Reilly, 2013.

Vereiste voorkennis
The students should have basic knowledge of computer networks.

Doelgroep
mBA, mCS, mPDCS, mEct

Programming Large-scale Parallel Systems

Vakcode	XM_40017 ()
Periode	Periode 1
Credits	6.0
Voertaal	Engels
Faculteit	Faculteit der Exacte Wetenschappen
Coördinator	prof. dr. ir. H.E. Bal
Examinator	prof. dr. ir. H.E. Bal
Docent(en)	prof. dr. ir. H.E. Bal
Lesmethode(n)	Hoorcollege
Niveau	400

Doel vak
You will
- be introduced to the domain of High Performance Computing (HPC)
- learn about design methods for parallel algorithms
- compare different parallel computer architectures

- analyze performance of network topologies
- develop basic familiarity with a range of parallel programming constructs,
environments and languages
- gain insight into some selected parallel applications

Inhoud vak
This lecture discusses how programs can be written that run in parallel on a large number of processors, with the main goal of reducing execution
time. The class has a brief introduction into parallel computing systems (architectures). The focus of the class, however, is on programming methods, languages, and applications. Both traditional techniques (like MPI message passing) and more advanced techniques like parallel object-oriented approaches from the Java ecosystem or dedicated HPC programming languages will be
discussed. In particular, Cray's high productivity language Chapel is discussed in much more detail
(about 4 lectures).
Several parallel applications are
discussed, including nearest-neighbor stencil computations, N-body simulations and search algorithms.

Onderwijsvorm
Lectures (4 hours per week), given by prof.dr.ir. Henri Bal (VU) and Dr Clemens Grelck (UvA).
Interested students may also obtain an account on our DAS research cluster and do simple experiments with MPI.
There is also a separate Parallel Programming
Practical (6 ECTS) in P2 and P3 whose aim is to complement the contents of this course with practical skills and experience. That course makes heavy use of DAS.

Toetsvorm
Written exam

Literatuur
Papers will be made available on Canvas

Doelgroep
mAI, mBIO, mCS, mPDCS, m Computational Science

Overige informatie
Lecturers:
prof.dr.ir. Henri Bal (VU)
Dr. Clemens Grelck (UvA)

Project Optimization of Business Processes

Vakcode	X_400213 (400213)
Periode	Periode 3
Credits	6.0
Voertaal	Engels
Faculteit	Faculteit der Exacte Wetenschappen
Coördinator	dr. R. Bekker
Examinator	dr. R. Bekker

Lesmethode(n)	Hoorcollege, Practicum
Niveau	500

Doel vak
Acquiring skills and experience necessary for building decision support systems, and learning to apply relevant scientific knowledge.

Inhoud vak
Project optimization of business processes concerns the construction and/or design of (part of) a decision support system (DSS) that:
- is designed and built in a scientifically sound way;
- can be used in practice (the DSS is built in VBA).
The DSS is built in groups of students.

Onderwijsvorm
Project

Toetsvorm
Individual test for VBA, individual grade for participation in group project based on observed participation and a short oral exam.

Literatuur
None.

Aanbevolen voorkennis
Applied Stochastic Modeling (X_400392).

Doelgroep
mBA, mBA-D

Overige informatie
Important note: you are expected to attend the kick-off meeting. If (due to circumstances) you are not able to attend this meeting, you should notify the lecturer in advance. Failing to do so may exclude you from this course.

Quantitative Financial Risk Management

Vakcode	E_FIN_QFRM (60422110)
Periode	Periode 4
Credits	6.0
Voertaal	Engels
Faculteit	School of Business and Economics
Coördinator	dr. S.A. Borovkova
Examinator	dr. S.A. Borovkova
Docent(en)	dr. S.A. Borovkova, dr. A. van Haastrecht
Lesmethode(n)	Hoorcollege, Werkcollege
Niveau	400

Doel vak
Deep understanding and ability to implement modern quantitative risk measurement and management techniques, in the areas of market, operational and liquidity risk.

Inhoud vak
The lecturers are Dr. S. Borovkova, an expert on derivatives and quantitative risk
management. We will focus on financial risks facing corporations and financial institutions, such
as market, liquidity and operational risks (note that credit risk is handled in a separate course Credit, Complexity and Systemic Risk). The course will encompass both
theoretical and applied aspects of risk management. This course will give you a solid fundamental for measurement and management of financial risks, knowledge of newest quantitative methods and the ability to apply your knowledge in corporate environment. The lectures are complemented by practical assignments designed to maximally match actual risk management applications in banking environment. For this course you need a strong quantitative focus and affiliation with statistics and probability as well as (some) affiliation with finance, or an intention to learn necessary concepts and vocabulary.

Onderwijsvorm
Lectures (4 hours per week) and practice sessions (2 hours a week)

Toetsvorm
2 practical assignments and written exam

Literatuur
Embrechts, Frey and McNeal "Quantitative Risk Management"

Aanbevolen voorkennis
Introductory statistics and probability, implementation skills (Matlab, R, Python or any other computer package)

Research Paper Business Analytics

Vakcode	X_400206 (400206)
Periode	Ac. Jaar (september)
Credits	6.0
Voertaal	Engels
Faculteit	Faculteit der Exacte Wetenschappen
Coördinator	drs. H.J.M. van Goor-Balk
Examinator	dr. R. Bekker
Lesmethode(n)	Hoorcollege
Niveau	500

Doel vak
The objective of the Research Paper Business Analytics is to:
- demonstrate the student's ability to describe a problem in a clear manner (the report should therefore be concise and 'to the point') for the benefit of an expert manager.
- represent the results of relatively basic research (including any desk study required) which has been conducted entirely by the student concerned. 'Co-productions' are not permitted.
- present the results of that research in an appropriately academic manner. This requirement also applies to the verbal presentation.
- be completed within the allotted period (to include all required

research activities).

Inhoud vak
As part of the BA programme, students are required to produce a 'thesis'. This is an account of a research project undertaken by the student further to a specific problem statement. The input for this research may involve the use of computer-generated data, although it can also be drawn from the existing literature.

The student records his or her findings in a written report - the research paper - and also gives a verbal presentation, both in English. The paper should emphasize the business-related aspects of the programme as well as the more fundamental aspects of mathematics and/or computer science.

Onderwijsvorm
Supervision by a staff member of preferably the Faculty of Science.

Toetsvorm
A written report and a verbal presentation (both in English).

Doelgroep
mBA

Intekenprocedure
If you are planning to write your paper within two months, please register yourself in VUnet for this subject. You have to notify the internship coordinator (H.J.M.van.Goor-Balk@vu.nl) as soon as you have started with your Research Paper Business Analytics by sending her a mail with the name of your supervisor and your starting and finishing date.

Overige informatie
All the information about the Research Paper Business Analytics is to be found on Canvas. Students can also attend the information session about the Research Paper Business Analytics in April where staff members introduce themselves and provide the students with possible topics.

Scheduling

Vakcode	X_400396 (400396)
Periode	Periode 4+5
Credits	6.0
Voertaal	Engels
Faculteit	Faculteit der Exacte Wetenschappen
Coördinator	dr. R. Bekker
Examinator	dr. R. Bekker
Niveau	400

Inhoud vak
This course is part of the joint national master programme in Mathematics.
For schedules, course locations and course descriptions see https://elo.mastermath.nl/

Doelgroep
mMath, mBA

Intekenprocedure
You have to register your participation in each Mastermath course via https://elo.mastermath.nl/
Registration is mandatory and absolutely necessary for transferring your grades from Mastermath to the administration of your university.

Statistical Models

Vakcode	X_400418 (400418)
Periode	Periode 1+2
Credits	6.0
Voertaal	Engels
Faculteit	Faculteit der Exacte Wetenschappen
Coördinator	dr. E.N. Belitser
Examinator	dr. E.N. Belitser
Docent(en)	dr. E.N. Belitser
Lesmethode(n)	Hoorcollege
Niveau	400

Doel vak
The goals of this course are to get acquainted with some of the most commonly used statistical models, to learn how to apply these models in valid settings, and to understand the basic theory behind these models.

Inhoud vak
Analysis of Variance, Generalized Linear Models, Non-linear Models, Time Series.

Onderwijsvorm
Lectures and tutorials.

Toetsvorm
Assignments and examination.

Literatuur
Lecture notes "Statistical Models" by M.C.M. de Gunst.

Vereiste voorkennis
Statistics course.

Aanbevolen voorkennis
Linear Algebra, Probability Theory and Statistics. Statistical Data Analysis (X_401029)

Doelgroep
mBA, mBA-D, mMath

Overige informatie
Students will use statistical package R (www.r-project.org/) for data analysis.

Statistics for High-Dimensional Data

Vakcode	X_405113 ()
Periode	Periode 4+5
Credits	6.0
Voertaal	Engels
Faculteit	Faculteit der Exacte Wetenschappen
Coördinator	dr. M. van de Wiel
Examinator	dr. M. van de Wiel
Docent(en)	dr. M. van de Wiel
Lesmethode(n)	Hoorcollege
Niveau	400

Doel vak
Teaching students the adjustments to classical statistical methodology, necessary to tackle high-dimensional data.

Inhoud vak
This course gives an overview of statistical methods that are used for analyzing high-dimensional data sets in which many variables (often thousands) have been measured for a limited number of subjects. This type of data arises in genomics, where genetic information is measured for many thousands of genes simultaneously, in functional MRI imaging of the brain, and also in economic applications. The course covers some of the most important statistical issues for high-dimensional data, including: a) initial processing of the data; b) model-based statistical inference for Gaussian and count data (classical and Bayesian methods); c) multiple testing (family-wise error rate and false discovery rate control); d) prediction of binary endpoints (e.g. recurrence of a tumor) and survival; e) clustering of samples (e.g. to find tumor subtypes). Several specific types of high-dimensional data will be discussed and used during the course. In terms of applications the course focuses on cancer genomics, but theoretical aspects will apply to other fields as well.

Onderwijsvorm
Lectures + practical exercises

Toetsvorm
Written exam

Literatuur
Tutorial in biostatistics: multiple hypothesis testing in genomics" by Goeman & Solari (article in Statistics in Medicine) plus handouts provided by the lecturer

Aanbevolen voorkennis
Algemene statistitiek, Statistical Data Analysis

Doelgroep
mMath, mSFM

Statistics for Networks

Vakcode	X_405110 ()
Credits	6.0
Voertaal	Engels
Faculteit	Faculteit der Exacte Wetenschappen
Coördinator	prof. dr. M.C.M. de Gunst
Examinator	prof. dr. M.C.M. de Gunst
Docent(en)	prof. dr. M.C.M. de Gunst, dr. E.N. Belitser
Lesmethode(n)	Hoorcollege
Niveau	600

Doel vak
After this course students are acquainted with the main statistical methods and models for network analysis.

Inhoud vak
Researchers from diverse disciplines as biology, physics, sociology, economics, computer science and mathematics, are more and more involved with the collection, modeling and analysis of network data. The relational nature of network data means that statistical analysis of such data is generally more involved than the `standard' statistical analysis, that different mathematical models and different statistical methods are needed, and that different problems need to be faced. The aim of this course is to get students acquainted with the main methods and models for network analysis. The course focuses on the mathematical aspects of statistical modeling and statistical analysis of networks; computational aspects of network analysis will not be covered. Topics that will be discussed are: descriptive statistics for networks, network sampling, network modeling, inference for networks, and modeling and prediction for processes on network graphs.

Onderwijsvorm
Lectures, presentations, homework assignments.

Toetsvorm
Assignments, presentations.

Literatuur
- Statistical Analysis of Network Data by E.D. Kolaczyk, Springer, 2010.
- Additional material will be provided during the course.

Vereiste voorkennis
An introductory probability course, like Kansrekening 1 (X_400189) plus Kansrekening 2 (X_400190), and an introductory statistics course, like Algemene Statistiek (X_400004).

Aanbevolen voorkennis
Statistical Data Analysis (X_401029)

Doelgroep
XM_MAT_S 1, XM_MAT_AG 1, XM_SFM

Overige informatie
This course will not be taught in the academic year 2017-2018.

Stochastic Optimization

Vakcode	X_400336 (400336)
Periode	Periode 1+2
Credits	6.0
Voertaal	Engels
Faculteit	Faculteit der Exacte Wetenschappen
Coördinator	prof. dr. S. Bhulai
Examinator	prof. dr. S. Bhulai
Docent(en)	prof. dr. S. Bhulai
Lesmethode(n)	Hoorcollege
Niveau	400

Doel vak
The goal of the course is to discuss techniques from the field of stochastic optimization and their applications.

Inhoud vak
This course deals with the theory and algorithms for stochastic optimization with an application to controlled stochastic systems (e.g., call center management, inventory control, optimal design of communication networks). We discuss aspects of semi-Markov decision theory and their applications in certain queueing systems. In a programming assignment, students learn to implement optimization algorithms and experiment with them. Experience with and insight into the more theoretical subject is obtained through homework exercises.

Onderwijsvorm
Lectures.

Toetsvorm
Programming and written exercises, final exam.

Literatuur
Lecture notes will be posted on Canvas.

Vereiste voorkennis
A programming language.

Aanbevolen voorkennis
Stochastische Processen (X_400646) and Wachtrijmodellen (X_401061) or equivalent courses on Stochastic Processes and Queueing Theory.

Doelgroep
mBA, mBa-D, mMath, mSFM.

Stochastic Processes for Finance

Vakcode	X_400352 (400352)
Periode	Periode 1+2
Credits	6.0
Voertaal	Engels
Faculteit	Faculteit der Exacte Wetenschappen
Coördinator	dr. E.N. Belitser
Examinator	dr. E.N. Belitser

Docent(en)	prof. dr. J. van den Berg
Lesmethode(n)	Hoorcollege
Niveau	400

Doel vak
Learn basics of stochastic processes in continuous time, including the concepts of martingales and stochastic integration; apply these concepts to price options on stocks and interest rates by the no-arbitrage principle.

Inhoud vak
Financial institutions trade in risk, and it is therefore essential to measure and control such risks. Financial instruments such as options, swaps, forwards, etc. play an important role in risk management, and to handle them one needs to be able to price them. This course gives an introduction to the mathematical tools and theory behind risk management.

A "stochastic process" is a collection of random variables, indexed by a set T. In financial applications the elements of T model time, and T is the set of natural numbers (discrete time), or an interval in the positive real line (continuous time). "Martingales" are processes whose increments over an interval in the future have zero expectation given knowledge of the past history of the process. They play an important role in financial calculus, because the price of an option (on a stock or an interest rate) can be expressed as an expectation under a so-called martingale measure. In this course we develop this theory in discrete and continuous time. Most models for financial processes in continuous time are based on a special Gaussian process, called Brownian motion. We discuss some properties of this process and introduce "stochastic integrals" with Brownian motion as the integrator. Financial processes can next be modeled as solutions to "stochastic differential equations". After developing these mathematical tools we turn to finance by applying the concepts and results to the pricing of derivative instruments. Foremost, we develop the theory of no-arbitrage pricing of derivatives, which are basic tools for risk management.

Onderwijsvorm
Lectures and discussion of exercises

Toetsvorm
Assignments and written examination.

Literatuur
Lecture notes

Additional literature:
Shreve, "Stochastic Calculus for Finance I: The Binomial Asset Pricing Model", Springer;
Shreve, "Stochastic Calculus for Finance II: Continuous-time models", Springer.

Vereiste voorkennis
Probability (X_400622) and Analysis 1 (X_400005), or their equivalents.

Aanbevolen voorkennis

Measure Theory.

Doelgroep
mBA, mBA-D, mMath, mSFM, master Econometrics.

Overige informatie
A significant part of the course is used to introduce mathematical subjects and techniques like Brownian motion, stochastic integration and Ito calculus. In view of this, the course is NOT meant for students who already followed the master course "Stochastic Integration" or "Stochastic differential equations". On the other hand, after completing this course, students may be motivated to follow other courses (like the two mentioned above) where stochastic calculus is treated in a deeper and more rigorous way.

Text Mining

Vakcode	L_PABAALG002 ()
Periode	Periode 4
Credits	6.0
Voertaal	Engels
Faculteit	Faculteit der Geesteswetenschappen
Coördinator	dr. H.D. van der Vliet
Examinator	dr. H.D. van der Vliet
Docent(en)	drs. E. Maks, dr. H.D. van der Vliet, prof. dr. P.T.J.M. Vossen
Lesmethode(n)	Werkcollege, Hoorcollege
Niveau	300

Doel vak
You will get acquainted with the possibilities and problems of automatic analysis of natural language by computers. Students will obtain practical knowledge; they will learn to use existing technology and experience the obstacles and options of the domain. They will learn about the theories behind language technology and its connection to artificial intelligence, linguistics and semantic web. The students will choose a project themselves in which they apply the learned technologies,
evaluate its results and communicate their findings through a report.

Inhoud vak
It is estimated that about 80% of knowledge is captured in language: think of news, wikis, social media and handbooks. Searching for information is also largely done through language. The amount of information is too large for humans to oversee, which is why technologies are developed to access and use this information more efficiently.

Text Mining is a promising research domain whose goal it is to extract structured information from unstructured natural language. This is a big challenge as human language is a rich and complex medium that is to be understood in the context of social human interaction. Therefore, language technology analyses language on different levels: the grammatical level (e.g. word types and syntax), and the semantic level (e.g. entities, events, opinions). During the course you will learn how

this information is coded in text and how you can extract and present it using computers.

Onderwijsvorm
Lectures (2 hours/week) and labs (2 hours/week).

Toetsvorm
Assignments and exam
15% presentation of final assignment (group)
35% written report on final assignment (group)
50% exam
None of the grades can be lower than 5.5 to pass the course.
Attendance at the final assignment presentation session is mandatory and 4 out of 5 practical assignment need to be passed.

Literatuur
Diana Maynard, Kalina Bontcheva and Isabelle Augenstein (2016) Natural Language Processing for the Semantic Web. Morgan Claypool. ISBN: 9781627059091
+ Research papers that will be made available through Canvas
Steven Bird, Ewan Klein and Edward Loper (2009) Natural Language Processing with Python - Analyzing Text with the Natural LanguageToolkit. O'Reilly

Vereiste voorkennis
None

Aanbevolen voorkennis
Information Retrieval and Python

Doelgroep
3IMM, 3LI, BA

Overige informatie
This module is compulsory in the third year of Lifestyle Informatics and elective for Informatie, Multimedia & Management, Business Analytics. The course can
only be completed if the grades for the test components (assignment + exam) are at least 5.5 each, with a weighted average of more than 6, and 4 out of 5 practical assignments were passed. Attendance at the final event where students present their final assignments is compulsory.

This course is also interesting to students from other faculties as many fields deal with text and can benefit from automated text analysis (e.g. digital humanities, financial domain). Specific prior knowledge is not required, but affinity with computers is needed as the lab sessions and assignment require some Python programming.