DATA SCIENCE

The Computer Science Department:
Department website: http://www.cs.columbia.edu
Office location: 450 Mudd
Office contact: ug-advising@cs.columbia.edu
Director of Undergraduate Studies: Dr. Jae Woo Lee, 715 CEPSR; 212-939-7066; jae@cs.columbia.edu
Undergraduate Administrator: CS Advising, ug-advising@cs.columbia.edu

The Computer Science Major
Students study a common core of fundamental topics, supplemented by a program of six electives that provides a high degree of flexibility. Three of the electives are chosen from a list of upper-level courses that represent area foundations within computer science. The remaining electives are selected from the complete list of upper-level computer science courses. Students are encouraged to work with their faculty advisor to create a plan tailored to fit their goals and interests. The department webpage provides several example programs for students interested in a variety of specific areas in computer science.

Our website is always the most current in terms of information and has many FAQs for students. Please view this here: cs.columbia.edu and contact ug-advising@cs.columbia.edu with any questions.

Student Advising
Consulting Advisers
Undergraduate students will be assigned a CS Faculty Advisor from the list on the CS website - https://www.cs.columbia.edu/education/undergraduate/advisors/. Students will typically have the same advisor throughout their time in the program. However, students are encouraged to check this list at the start of every term to ensure their advisor remains the same. To reach out to your CS Faculty Advisor, please email first or visit during office hours.

Enrolling in Classes
Computer Science Department courses are needed by many student populations and are in high demand. To facilitate all COMS students getting the courses they need and distribute seats fairly, please refer to our policy - https://www.cs.columbia.edu/cs-course-registration-policy/

Preparing for Graduate Study
The department offers a number of options at the graduate level, including the MS Express. Please refer to our FAQs - https://www.cs.columbia.edu/education/admissions8/ - or email ms-admissions@cs.columbia.edu with any questions.

Coursework Taken Outside of Columbia
Advanced Placement
The department grants 3 points for a score of 4 or 5 on the AP Computer Science A exam, along with an exemption from COMS W1004 Introduction to Computer Science and Programming in Java. However, we recommend that you take COMS W1004 before taking COMS W3134/W3137 Data Structures if you received a score of 4 or have not programmed in Java recently.

Barnard College Courses
Any course offered by the Computer Science @Barnard department can count toward degree requirements. Please refer to the major and minor program information pages for specific information.

Transfer Courses
Up to four transfer courses are accepted toward the major. Up to two transfer courses are accepted toward the minor. Calculus, linear algebra, and probability/statistics courses can be transferred in addition to the four/two-course limits. Each course must be approved as equivalent by the faculty who teaches it at Columbia. Please refer to the guide here - https://www.cs.columbia.edu/education/undergraduate/#sec8

Study Abroad Courses
If you are considering studying abroad, please consult with the CS Advisor as soon as possible. Each course for potential incorporation into your CS major or minor must be approved as equivalent by the faculty who teaches it at Columbia.

Summer Courses
Any Computer Science or approved cognate course offered during the summer session will count towards the degree, with the exception of online-only courses, which do not count towards degree requirements.

Undergraduate Research and Senior Thesis
Undergraduate Research in Courses
COMS W3998 UNDERGRAD PROJECTS IN COMPUTER SCIENCE. 1.00-3.00 points.
Prerequisites: Approval by a faculty member who agrees to supervise the work.
Independent project involving laboratory work, computer programming, analytical investigation, or engineering design. May be repeated for credit. Consult the department for section assignment.

COMS W4901 Projects in Computer Science. 1-3 points.
Prerequisites: Approval by a faculty member who agrees to supervise the work.
A second-level independent project involving laboratory work, computer programming, analytical investigation, or engineering design. May be repeated for credit, but not for a total of more than 3 points of degree credit. Consult the department for section assignment.

Senior Thesis Coursework and Requirements
A thesis is not a requirement for the major or minor.

COMS W3902 UNDERGRADUATE THESIS. 0.00-6.00 points.
Prerequisites: Agreement by a faculty member to serve as thesis adviser. An independent theoretical or experimental investigation by an undergraduate major of an appropriate problem in computer science carried out under the supervision of a faculty member. A formal written report is mandatory and an oral presentation may also be required. May be taken over more than one term, in which case the grade is deferred until all 6 points have been completed. Consult the department for section assignment.
Undergraduate Research Outside of Courses

Laboratory Facilities

The department has well-equipped lab areas for research in computer graphics, computer-aided digital design, computer vision, databases and digital libraries, data mining and knowledge discovery, distributed systems, mobile and wearable computing, natural language processing, networking, operating systems, programming systems, robotics, user interfaces, and real-time multimedia.

Research labs contain several large Linux and Solaris clusters; Puma 500 and IBM robotic arms; a UTAH-MIT dexterous hand; an Adept-1 robot; three mobile research robots; a real-time defocus range sensor; interactive 3-D graphics workstations with 3-D position and orientation trackers; prototype wearable computers, wall-sized stereo projection systems; see-through head-mounted displays; a networking testbed with three Cisco 7500 backbone routers, traffic generators; an IDS testbed with secured LAN, Cisco routers, EMC storage, and Linux servers; and a simulation testbed with several Sun servers and Cisco Catalyst routers. The department uses a SIP IP phone system. The protocol was developed in the department.

The department’s computers are connected via a switched 1Gb/s Ethernet network, which has direct connectivity to the campus OC-3 Internet and internet 2 gateways. The campus has 802.11b/g wireless LAN coverage.

The research facility is supported by a full-time staff of professional system administrators and programmers.

Participating in Research Projects

Students can reach out to professors whose research areas are of interest to them. Professors will typically require that students have completed the relevant coursework covering the background knowledge and skills.

Once a faculty member agrees to supervise the student’s research work, the student will register for the professor’s section of COMS W3998 or W4901.

COMS W3998 UNDERGRAD PROJECTS IN COMPUTER SCIENCE. 1.00-3.00 points.
Prerequisites: Approval by a faculty member who agrees to supervise the work.

Independent project involving laboratory work, computer programming, analytical investigation, or engineering design. May be repeated for credit. Consult the department for section assignment.

COMS W4901 Projects in Computer Science. 1-3 points.
Prerequisites: Approval by a faculty member who agrees to supervise the work.

A second-level independent project involving laboratory work, computer programming, analytical investigation, or engineering design. May be repeated for credit, but not for a total of more than 3 points of degree credit. Consult the department for section assignment.

Department Honors and Prizes

Department Honors

The Computer Science Department does not award departmental honors.

Academic Prizes

Jonathan L. Gross Award for Academic Excellence: This award was established in 2017 in honor of the much loved Professor Emeritus Jonathan Gross. Each year a cash gift is awarded to one graduating masters student and to one graduating senior from each of the four undergraduate schools served by the Department of Computer Science.

Theodore R. Bashkow Award: Presented to a computer science senior who has excelled in independent projects. This is awarded in honor of Professor Theodore R. Bashkow, whose contributions as a researcher, teacher, and consultant have significantly advanced the state of the art of computer science.

Andrew P. Kosoresow Memorial Award for Excellence in Teaching and Service: Awarded for outstanding contributions to teaching in the Department of Computer Science and exemplary service to the Department and its mission.

Computer Science Scholarship Award: A cash prize awarded to two B.A. and two B.S. degree candidates for outstanding academic achievement in computer science.

Russell C. Mills Award: This annual award, established by the computer science department in 1992 in memory of Russell C. Mills, is a cash prize given to a computer science major who has exhibited excellence in the area of computer science.

Other Important Information

See the Requirements section for the policies on double counting and D grades.

Professors

Peter N. Belhumeur
Steven M. Bellovin
Luca Carloni
Xi Chen
Steven K. Feiner
Luis Gravano
Julia B. Hirschberg
Gail E. Kaiser
John R. Kender
Tal Malkin
Kathleen R. McKeown
Vishal Misra
Shree Kumar Nayar
Jason Nieh
Christos Papadimitriou
Itsik Pe’er
Toniann Pitassi
Kenneth A. Ross
Tim Roughgarden
Daniel S. Rubenstein
Henning G. Schulzrinne
Rocco A. Servedio
Simha Sethumadhavan
Salvatore J. Stolfo
Bjarne Stroustrup
Vladimir Vapnik
Jeannette Wing
Junfeng Yang
Mihalis Yannakakis
Richard Zemei

Associate Professors
Alexandr Andoni
Elias Bareinboim
Augustin Chaintreau
Stephen A. Edwards
Roxana Geambasu
Daniel Hsu
Suman Jana
Martha Allen Kim
Baishakhi Ray
Carl Vondrick
Eugene Wu
Zhou Yu
Changxi Zheng
Xia Zhou

Assistant Professors
Josh Alman
Lydia Chilton
Ronghui Gu
Kostis Kaffes
David Knowles
Brian Smith
Henry Yuen

Senior Lecturer in Discipline
Paul Blaer
Adam Cannon
Jae Woo Lee

Lecturer in Discipline
Daniel Bauer
Brian Borowski
Tony Dear

Associated Faculty Joint
Andrew Blumberg
Shih-Fu Chang
Feniosky Peña-Mora
Clifford Stein

Affiliates
Shipra Agrawal
Mohammed AlQuraishi
Elham Azizi
Paolo Blikstein
Asaf Cidon
Matei Ciocarlie
Rachel Cummings
Noemie Elhadad
Javad Ghaderi
Gamze Gursoy
Xiaofan Jiang
Ethan Katz-Bassett
Hod Lipson
Smaranda Muresan
Liam Paninski

Brian Plancher
Mark Santolucito
Lisa Soros
Barbara Tversky
Venkat Venkatasubramanian
Rebecca Wright
Gil Zussman

Senior Research Scientists
Gaston Ormazabal
Moti Yung

Emeritus
Alfred V. Aho
Peter K. Allen
Edward G. Coffman Jr.
Zvi Galil
Jonathan L. Gross
Steven M. Nowick
Stephen H. Unger
Henryk Wozniakowski
Yechiam Yemini

Guidance for Undergraduate Students in the Department

Program Planning for all Students
The following requirements are new as of the academic year 2023-2024. Students who declared a CS major in the academic year 2022-2023 or earlier have the option to follow the old requirements. The old requirements are noted on the Undergraduate Programs pages of the Computer Science Department website (https://www.cs.columbia.edu/education/undergraduate/).

Please note that the information on the department website is more up-to-date than the information in the archived Bulletins. Students with questions about which requirements to follow are advised to talk with ug-advising@cs.columbia.edu.

Restrictions on overlapping courses
Students may receive credit for only one of the following two courses:

- **COMS W1004** Introduction to Computer Science and Programming in Java
- **COMS W1005** Introduction to Computer Science and Programming in MATLAB.

Students may receive credit for only one of the following three courses:

- **COMS W3134** Data Structures in Java
- **COMS W3136** ESSENTIAL DATA STRUCTURES
- **COMS W3137** HONORS DATA STRUCTURES # ALGOL

COMS W1005 and COMS W3136 cannot be counted towards the Computer Science major, minor, and concentration.
Data Science

No more than 6 points of project/thesis courses (COMS W3902, W3998, W4901) can count toward the major. COMS W3999 Fieldwork cannot be used as a CS Elective.

No more than one course from each set below may be applied toward the computer science major:

- IEOR E3658, STAT UN1201, MATH UN2015
- MATH UN2015, MATH UN2010, APAM E3101, COMS W3251
- COMS W4771, COMS W4721

Double Counting
Double-counting policies are to be construed within the larger double-counting policy of the student's home school. Double-counting policies are detailed on each School's Bulletin and/or Catalog.

The CS department allows the following courses in the CS Core and Mathematics requirement to be double-counted with another major, minor, or concentration. No other courses can be double-counted with another program.

- COMS W1004
- Any calculus courses (including Honors Math A and B)
- One Linear Algebra course
- One Probability/Statistics course

Grading
A maximum of one course worth no more than 4 points passed with a grade of D may be counted toward the major or minor.

Course Numbering Structure
The first digit indicates the level of the course, as follows:

0 Course that cannot be credited toward any degree
1 Undergraduate course
2 Undergraduate course, intermediate
3 Undergraduate course, advanced
4 Graduate course that is open to qualified undergraduates
6 Graduate course
8 Graduate research course or seminar

Guidance for First-Year Students

Pre-Introductory Courses
COMS W1004 is the first course in the Computer Science major curriculum, and it does not require any previous computing experience. Before taking COMS W1004, however, students have an option to start with one of the pre-introductory courses: ENGI E1006 or COMS W1002.

ENGI E1006 Introduction to Computing for Engineers and Applied Scientists is a general introduction to computing for STEM students. ENGI E1006 is in fact a required course for all engineering students. COMS W1002 Computing in Context is a course primarily intended for humanities majors, but it also serves as a pre-introductory course for CS majors. ENGI E1006 and COMS W1002 do not count towards Computer Science major.

Guidance for Transfer Students
Up to four transfer courses are accepted toward the major. Up to two transfer courses are accepted toward the minor or concentration. Calculus, linear algebra, and probability/statistics courses can be transferred in addition to the four/two-course limits.

Undergraduate Programs of Study

Major in Computer Science
All majors should confer with their program adviser each term to plan their programs of study. Students considering a major in computer science are encouraged to talk to a program adviser during their first or second year. The Computer Science major is composed of four basic components: The Mathematics Requirement, the Computer Science Core, the Area Foundation Courses, and the Computer Science Electives.

Mathematics Requirement (6-11 points)

Calculus Requirement: Select one of the following courses:
- MATH UN1201 CALCULUS III
- MATH UN1205 ACCELERATED MULTIVARIABLE CALC
- APMA E2000 MULTIV. CALC. FOR ENGI # APP SCI

Note that MATH UN1201 (Calculus III) requires Calculus I as a prerequisite but does NOT require Calculus II. MATH UN1205 and APMA E2000, however, require both Calculus I and Calculus II as prerequisites.

Linear Algebra Requirement: Select one of the following courses:
- COMS W3251 COMPUTATIONAL LINEAR ALGEBRA (recommended)
- MATH UN2010 LINEAR ALGEBRA
- MATH UN2015 Linear Algebra and Probability
- MATH UN2020 Honors Linear Algebra
- APMA E2101 INTRO TO APPLIED MATHEMATICS
- APMA E3101 APPLIED MATH I: LINEAR ALGEBRA

Probability / Statistics Requirement: Select one of the following courses:
- MATH UN2015 Linear Algebra and Probability
- IEOR E3658 PROBABILITY FOR ENGINEERS
- STAT UN1201 CALC-BASED INTRO TO STATISTICS
- STAT GU4001 INTRODUCTION TO PROBABILITY AND STATISTICS

NOTE: Math 2015 Linear Algebra and Probability may simultaneously satisfy both linear algebra and probability requirements without the need to take additional classes thus reducing the total number of points required.

Pre-intro course (Optional, 3-4 points)
- ENGI E1006 INTRO TO COMP FOR ENG/APP SCI (recommended but not required)
  or COMS W1002 COMPUTING IN CONTEXT

Computer Science Core (20-21 points):

First Year
- COMS W1004 Introduction to Computer Science and Programming in Java
  or COMS W1007

Sophomore Year
- COMS W3134 Data Structures in Java
Major in Computer Science - Mathematics

For a description of the joint major in computer science—mathematics, see the Mathematics section in this bulletin.

Major in Information Science

The major in information science requires a minimum of 33 points, including a core requirement of five courses. Adjustments were made to the course lists below in March 2022.

The elective courses must be chosen with a faculty adviser to focus on the modeling and use of information within the context of a disciplinary theme. After discussing potential selections, students prepare a proposal of study that must be approved by the faculty adviser. In all cases, the six courses must be at the 3000 level or above, with at least three courses chosen from computer science. Following are some example programs. For more examples or templates for the program proposal, see a faculty adviser.

Note: In most cases, additional courses will be necessary as prerequisites in order to take some of the elective courses. This will depend on the student’s proposed program of study.

Core Requirement

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMS W1001</td>
<td>Introduction to Information Science</td>
</tr>
<tr>
<td>or COMS W1002</td>
<td>Computing in Context</td>
</tr>
<tr>
<td>COMS W1004</td>
<td>Introduction to Computer Science and</td>
</tr>
<tr>
<td></td>
<td>Programming in Java</td>
</tr>
<tr>
<td>COMS W3107</td>
<td>Clean Object-Oriented Design</td>
</tr>
<tr>
<td>COMS W3134</td>
<td>Data Structures in Java</td>
</tr>
<tr>
<td>STAT GU4001</td>
<td>INTRODUCTION TO PROBABILITY AND</td>
</tr>
<tr>
<td></td>
<td>STATISTICS</td>
</tr>
</tbody>
</table>

Following are some suggested programs of instruction:

Information Science and Contemporary Society

Students may focus on how humans use technology and how technology has changed society.

The requirements include:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMS W4111</td>
<td>INTRODUCTION TO DATABASES</td>
</tr>
<tr>
<td>COMS W4701</td>
<td>ARTIFICIAL INTELLIGENCE</td>
</tr>
<tr>
<td>COMS W3410</td>
<td>COMPUTERS AND SOCIETY</td>
</tr>
<tr>
<td>SOCI UN3010</td>
<td>METHODS FOR SOCIAL RESEARCH</td>
</tr>
<tr>
<td>SOCI UN3960</td>
<td>SEMINAR - PROBLEMS OF LAW #</td>
</tr>
<tr>
<td></td>
<td>SOCIETY</td>
</tr>
</tbody>
</table>

Information Science and the Economy

Students may focus on understanding information modeling together with existing and emerging needs in economics and finance as well as algorithms and systems to address those needs.

The requirements include:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMS W4111</td>
<td>INTRODUCTION TO DATABASES</td>
</tr>
<tr>
<td>COMS W4701</td>
<td>ARTIFICIAL INTELLIGENCE</td>
</tr>
<tr>
<td>COMS W4771</td>
<td>MACHINE LEARNING</td>
</tr>
<tr>
<td>ECON UN3412</td>
<td>INTRODUCTION TO ECONOMETRICS</td>
</tr>
</tbody>
</table>

Restrictions

No more than 6 points of project/thesis courses (COMS W3902, W3998, W4901) can count toward the major. COMS W3999 Fieldwork cannot be used as a CS Elective.

No more than one course from each set below may be applied towards the computer science major:

- IEDR E3658, STAT UN1201, MATH UN2015
- MATH UN2015, MATH UN2010, APAM E3101, COMS W3251
- COMS W4771, COMS W4721

Major in Computational Biology

For a description of the joint major in computer science—Biology, see the Biological Sciences section in this bulletin.
ECON UN3025  FINANCIAL ECONOMICS
ECON UN3265  MONEY AND BANKING

**Information Science and Health Sciences**

Students may focus on understanding information modeling together with existing and emerging needs in health sciences, as well as algorithms and systems to address those needs.

The requirements include:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMS W4111</td>
<td>INTRODUCTION TO DATABASES</td>
</tr>
<tr>
<td>COMS W4170</td>
<td>USER INTERFACE DESIGN</td>
</tr>
<tr>
<td>COMS W4701</td>
<td>ARTIFICIAL INTELLIGENCE</td>
</tr>
<tr>
<td>BINF G4001</td>
<td></td>
</tr>
<tr>
<td>BIOL W4037</td>
<td>Bioinformatics of Gene Expression</td>
</tr>
<tr>
<td>ECBM E3060/E4060</td>
<td></td>
</tr>
</tbody>
</table>

**Major in Data Science**

In response to the ever-growing importance of "big data" in scientific and policy endeavors, the last few years have seen explosive growth in theory, methods, and applications at the interface between computer science and statistics. The statistics and computer science departments have responded with a joint major that emphasizes the interface between the disciplines.

**Prerequisites (15 points)**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH UN1101</td>
<td>CALCULUS I</td>
</tr>
<tr>
<td>MATH UN1102</td>
<td>CALCULUS II</td>
</tr>
<tr>
<td>MATH UN1201</td>
<td>CALCULUS III</td>
</tr>
<tr>
<td>MATH UN2010</td>
<td>LINEAR ALGEBRA</td>
</tr>
</tbody>
</table>

This introductory Statistics course:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>STAT UN1201</td>
<td>CALC-BASED INTRO TO STATISTICS</td>
</tr>
</tbody>
</table>

**Statistics (12 points)**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>STAT GU4203</td>
<td>PROBABILITY THEORY</td>
</tr>
<tr>
<td>STAT GU4204</td>
<td>STATISTICAL INFERENCE</td>
</tr>
<tr>
<td>STAT GU4205</td>
<td>LINEAR REGRESSION MODELS</td>
</tr>
<tr>
<td>STAT GU4241</td>
<td>STATISTICAL MACHINE LEARNING</td>
</tr>
<tr>
<td>or COMS W4771</td>
<td>Machine Learning</td>
</tr>
</tbody>
</table>

**Computer Science (12 points)**

Select one of the following courses:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMS W1004</td>
<td>Introduction to Computer Science and Programming in Java</td>
</tr>
<tr>
<td>COMS W1005</td>
<td>Introduction to Computer Science and Programming in MATLAB</td>
</tr>
<tr>
<td>COMS W1007</td>
<td>ENGI E1006 INTRO TO COMP FOR ENG/APP SCI</td>
</tr>
</tbody>
</table>

Select one of the following courses:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMS W3134</td>
<td>Data Structures in Java</td>
</tr>
<tr>
<td>COMS W3136</td>
<td>ESSENTIAL DATA STRUCTURES</td>
</tr>
<tr>
<td>COMS W3137</td>
<td>HONORS DATA STRUCTURES # ALGOL</td>
</tr>
</tbody>
</table>

Two required courses:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMS W3203</td>
<td>DISCRETE MATHEMATICS</td>
</tr>
<tr>
<td>CSOR W4231</td>
<td>ANALYSIS OF ALGORITHMS I</td>
</tr>
</tbody>
</table>

**Electives (15 points)**

Select two of the following courses:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>STAT UN3106</td>
<td>APPLIED MACHINE LEARNING</td>
</tr>
<tr>
<td>STAT GU4206</td>
<td>STAT COMP # INTRO DATA SCIENCE</td>
</tr>
</tbody>
</table>

**Minor in Computer Science**

Students who pass the Computer Science Advanced Placement Exam A with a 4 or 5 will receive 3 points and an exemption from COMS W1004.

The Computer Science Minor consists of 6 courses as follows:

1. COMS W1004: Intro to computer science and programming in Java (3) or COMS W1007: Honors intro to comp sci (3)
2. COMS W3134: Data structures in Java (3) or COMS W3137: Honors data structures and algorithms (4)
3. COMS W3203: Discrete mathematics (4)
4. One course of the following:
   - COMS W3157: Advanced programming (4)
   - COMS W3261: Comp science theory (3)
   - CSEE W3827: Fundamentals of computer systems (3)
5. Any 3000-level or 4000-level COMS/CSXX/XXCS course of at least 3 points
6. Any 3000-level or 4000-level COMS/CSXX/XXCS course of at least 3 points OR one linear algebra or probability/statistics course from the following: APMA E3101, APMA E2101, MATH UN2010, MATH UN2015, IEOR E3658, STAT UN1201, STAT GU4001 or STAT GU4203.

**Restrictions**

No more than 6 points of project/thesis courses (COMS W3902, W3998, W4901) can count toward the major. COMS W3999 Fieldwork cannot be used as a CS Elective.

No more than one course from each set below may be applied towards the computer science major:

- IEOR E3658, STAT UN1201, MATH UN2015
- MATH UN2015, MATH UN2010, APAM E3101, COMS W3251
- COMS W4771, COMS W4721
For students who entered Columbia in or before the 2023-24 academic year

Concentration in Computer Science
The concentration in computer science requires a minimum of 22-24 points, as follows:

COMS W1004 Introduction to Computer Science and Programming in Java
or COMS W1007

COMS W3134 Data Structures in Java
or COMS W3137

COMS W3157 Advanced Programming

COMS W3203 Discrete Mathematics

CSEE W3827 Fundamentals of Computer Systems (or any 3-point 4000-level computer science course)

Select one of the following courses:

COMS W3251 Computational Linear Algebra

MATH UN2010 Linear Algebra

MATH UN2015 Linear Algebra and Probability

MATH V2020 Honors Linear Algebra

APMA E2101 Intro to Applied Mathematics

APMA E3101 Applied Math I: Linear Algebra

IEOR E3658 Probability for Engineers

STAT UN1201 Calc-Based Intro to Statistics

STAT GU4001 Introduction to Probability and Statistics

Computer Science
COMS W1001 Introduction to Information Science. 3 points.
Lect: 3.

Basic introduction to concepts and skills in Information Sciences: human-computer interfaces, representing information digitally, organizing and searching information on the internet, principles of algorithmic problem solving, introduction to database concepts, and introduction to programming in Python.

COMS W1002 Computing in Context. 4.00 points.
CC/GS: Partial Fulfillment of Science Requirement

Introduction to elementary computing concepts and Python programming with domain-specific applications. Shared CS concepts and Python programming lectures with track-specific sections. Track themes will vary but may include computing for the social sciences, computing for economics and finance, digital humanities, and more. Intended for nonmajors. Students may only receive credit for one of ENGI E1006 or COMS W1002

COMS W1003 Intro-Comput Sci/Program in C. 3.00 points.
COMS W1004 Introduction to Computer Science and Programming in Java. 3 points.
Lect: 3.

A general introduction to computer science for science and engineering students interested in majoring in computer science or engineering. Covers fundamental concepts of computer science, algorithmic problem-solving capabilities, and introductory Java programming skills. Assumes no prior programming background. Columbia University students may receive credit for only one of the following two courses: 1004 or 1005.
COMS W1011 INTERMED COMPUTER PROGRAMMING. **3.00 points.**

COMS W1012 COMPUTING IN CONTEXT REC. **0.00 points.**

**Fall 2024: COMS W1012**

<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMS 1012</td>
<td>001/11921</td>
<td>Th 7:10pm - 8:00pm 227 Seeley W. Mudd Building</td>
<td>Adam Cannon</td>
<td>0.00</td>
<td>0/40</td>
</tr>
<tr>
<td>COMS 1012</td>
<td>002/11922</td>
<td>Th 7:10pm - 8:00pm 644 Seeley W. Mudd Building</td>
<td>Adam Cannon</td>
<td>0.00</td>
<td>0/40</td>
</tr>
<tr>
<td>COMS 1012</td>
<td>003/11923</td>
<td>F 10:10am - 11:00am 307 Uris Hall</td>
<td>Adam Cannon</td>
<td>0.00</td>
<td>0/40</td>
</tr>
<tr>
<td>COMS 1012</td>
<td>004/11924</td>
<td>F 2:00pm - 2:50pm 307 Uris Hall</td>
<td>Adam Cannon</td>
<td>0.00</td>
<td>0/40</td>
</tr>
<tr>
<td>COMS 1012</td>
<td>005/11925</td>
<td>Th 7:10pm - 8:00pm 415 Schapiro Cepser</td>
<td>Adam Cannon</td>
<td>0.00</td>
<td>0/40</td>
</tr>
<tr>
<td>COMS 1012</td>
<td>006/11926</td>
<td>Th 7:10pm - 8:00pm 825 Seeley W. Mudd Building</td>
<td>Adam Cannon</td>
<td>0.00</td>
<td>0/40</td>
</tr>
<tr>
<td>COMS 1012</td>
<td>007/11927</td>
<td>F 9:00am - 9:50am 307 Uris Hall</td>
<td>Adam Cannon</td>
<td>0.00</td>
<td>0/40</td>
</tr>
<tr>
<td>COMS 1012</td>
<td>008/11928</td>
<td>Th 7:10pm - 8:00pm 401 Chandler</td>
<td>Adam Cannon</td>
<td>0.00</td>
<td>0/30</td>
</tr>
<tr>
<td>COMS 1012</td>
<td>009/11929</td>
<td>F 10:10am - 11:00am 608 Schermerhorn Hall</td>
<td>Adam Cannon</td>
<td>0.00</td>
<td>0/30</td>
</tr>
<tr>
<td>COMS 1012</td>
<td>010/11930</td>
<td>Th 7:10pm - 8:00pm 233 Seeley W. Mudd Building</td>
<td>Adam Cannon</td>
<td>0.00</td>
<td>0/30</td>
</tr>
<tr>
<td>COMS 1012</td>
<td>011/11931</td>
<td>F 11:00am - 11:50am 307 Uris Hall</td>
<td>Adam Cannon</td>
<td>0.00</td>
<td>0/30</td>
</tr>
</tbody>
</table>

COMS W1103 HONORS INTRO COMPUTER SCIENCE. **3.00 points.**

COMS W1404 EMERGING SCHOLARS PROG SEMINAR. **1.00 point.**

Pass/Fail only.

Prerequisites: the instructor’s permission. Corequisites: COMS W1002 or COMS W1004 or COMS W1007

Corequisites: COMS W1004, COMS W1007, COMS W1002

Peer-led weekly seminar intended for first and second year undergraduates considering a major in Computer Science. Pass/fail only. May not be used towards satisfying the major or SEAS credit requirements

**Spring 2024: COMS W1404**

<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMS 1404</td>
<td>001/12053</td>
<td>F 8:40am - 9:55am 502 Northwest Corner</td>
<td>Adam Cannon</td>
<td>1.00</td>
<td>6/16</td>
</tr>
<tr>
<td>COMS 1404</td>
<td>002/12054</td>
<td>F 10:10am - 11:25am 502 Northwest Corner</td>
<td>Adam Cannon</td>
<td>1.00</td>
<td>3/16</td>
</tr>
<tr>
<td>COMS 1404</td>
<td>003/12055</td>
<td>F 11:40am - 12:55pm 502 Northwest Corner</td>
<td>Adam Cannon</td>
<td>1.00</td>
<td>0/16</td>
</tr>
<tr>
<td>COMS 1404</td>
<td>004/12056</td>
<td>F 1:10pm - 2:25pm 502 Northwest Corner</td>
<td>Adam Cannon</td>
<td>1.00</td>
<td>4/16</td>
</tr>
<tr>
<td>COMS 1404</td>
<td>005/12057</td>
<td>F 2:40pm - 3:55pm 502 Northwest Corner</td>
<td>Adam Cannon</td>
<td>1.00</td>
<td>6/16</td>
</tr>
<tr>
<td>COMS 1404</td>
<td>006/12058</td>
<td>F 4:10pm - 5:25pm 502 Northwest Corner</td>
<td>Adam Cannon</td>
<td>1.00</td>
<td>3/16</td>
</tr>
<tr>
<td>COMS 1404</td>
<td>007/12059</td>
<td>F 9:30am - 10:45am 253 Engineering Terrace</td>
<td>Adam Cannon</td>
<td>1.00</td>
<td>0/16</td>
</tr>
<tr>
<td>COMS 1404</td>
<td>008/12061</td>
<td>F 11:00am - 12:15pm 253 Engineering Terrace</td>
<td>Adam Cannon</td>
<td>1.00</td>
<td>5/16</td>
</tr>
<tr>
<td>COMS 1404</td>
<td>009/12063</td>
<td>F 12:30pm - 1:45pm 253 Engineering Terrace</td>
<td>Adam Cannon</td>
<td>1.00</td>
<td>9/16</td>
</tr>
<tr>
<td>COMS 1404</td>
<td>010/12064</td>
<td>F 2:00pm - 3:15pm 253 Engineering Terrace</td>
<td>Adam Cannon</td>
<td>1.00</td>
<td>3/16</td>
</tr>
</tbody>
</table>

**Fall 2024: COMS W1404**

<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMS 1404</td>
<td>001/11996</td>
<td>F 8:40am - 9:55am 253 Engineering Terrace</td>
<td>Adam Cannon</td>
<td>1.00</td>
<td>0/16</td>
</tr>
<tr>
<td>COMS 1404</td>
<td>002/11997</td>
<td>F 10:10am - 11:25am 253 Engineering Terrace</td>
<td>Adam Cannon</td>
<td>1.00</td>
<td>0/16</td>
</tr>
<tr>
<td>COMS 1404</td>
<td>003/11998</td>
<td>F 11:40am - 12:55pm 253 Engineering Terrace</td>
<td>Adam Cannon</td>
<td>1.00</td>
<td>0/16</td>
</tr>
<tr>
<td>COMS 1404</td>
<td>004/11999</td>
<td>F 1:10pm - 2:25pm 253 Engineering Terrace</td>
<td>Adam Cannon</td>
<td>1.00</td>
<td>0/16</td>
</tr>
<tr>
<td>COMS 1404</td>
<td>005/12000</td>
<td>F 2:40pm - 3:55pm 253 Engineering Terrace</td>
<td>Adam Cannon</td>
<td>1.00</td>
<td>0/16</td>
</tr>
<tr>
<td>COMS 1404</td>
<td>006/12001</td>
<td>F 4:10pm - 5:25pm 337 Seeley W. Mudd Building</td>
<td>Adam Cannon</td>
<td>1.00</td>
<td>0/16</td>
</tr>
<tr>
<td>COMS 1404</td>
<td>007/12002</td>
<td>F 9:30am - 10:45am 337 Seeley W. Mudd Building</td>
<td>Adam Cannon</td>
<td>1.00</td>
<td>0/16</td>
</tr>
<tr>
<td>COMS 1404</td>
<td>008/12003</td>
<td>F 11:00am - 12:15pm 337 Seeley W. Mudd Building</td>
<td>Adam Cannon</td>
<td>1.00</td>
<td>0/16</td>
</tr>
<tr>
<td>COMS 1404</td>
<td>009/12004</td>
<td>F 12:30pm - 1:45pm 337 Seeley W. Mudd Building</td>
<td>Adam Cannon</td>
<td>1.00</td>
<td>0/16</td>
</tr>
<tr>
<td>COMS 1404</td>
<td>010/12005</td>
<td>F 2:00pm - 3:15pm 337 Seeley W. Mudd Building</td>
<td>Adam Cannon</td>
<td>1.00</td>
<td>0/16</td>
</tr>
</tbody>
</table>
COMS W3011 INTERMED COMPUTER PROGRAMMING. 3.00 points.

COMS W3101 PROGRAMMING LANGUAGES. 1.00 point.

Lect: 1.

Prerequisites: Fluency in at least one programming language. Introduction to a programming language. Each section is devoted to a specific language. Intended only for those who are already fluent in at least one programming language. Sections may meet for one hour per week for the whole term, for three hours per week for the first third of the term, or for two hours per week for the first six weeks. May be repeated for credit if different languages are involved

COMS W3102 DEVELOPMENT TECHNOLOGY. 1.00-2.00 points.


Prerequisites: Fluency in at least one programming language. Introduction to software development tools and environments. Each section devoted to a specific tool or environment. One-point sections meet for two hours each week for half a semester, and two point sections include an additional two-hour lab

Spring 2024: COMS W3102

<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMS 3102</td>
<td>001/12065</td>
<td>F 6:10pm - 8:00pm</td>
<td>Shaib Ahamed</td>
<td>1.00-2.00</td>
<td>62/70</td>
</tr>
</tbody>
</table>

COMS W3107 Clean Object-Oriented Design. 3.00 points.

Prerequisites: Intro to Computer Science/Programming in Java (COMS W1004) or instructor’s permission. May not take for credit if already received credit for COMS W1007.

Prerequisites: see notes re: points

A course in designing, documenting, coding, and testing robust computer software, according to object-oriented design patterns and clean coding practices. Taught in Java. Object-oriented design principles include: use cases; CRC, UML; javadoc; patterns (adapter, builder, command, composite, decorator, facade, factory, iterator, lazy evaluation, observer, singleton, strategy, template, visitor); design by contract; loop invariants; interfaces and inheritance hierarchies; anonymous classes and null objects; graphical widgets; events and listeners; Java’s Object class; generic types; reflection; timers, threads, and locks

COMS W3123 ASSEMBLY LANG AND COMPUT LOGIC. 3.00 points.

COMS W3132 Intermediate Computing in Python. 4.00 points.

Essential data structures and algorithms in Python with practical software development skills, applications in a variety of areas including biology, natural language processing, data science and others

Spring 2024: COMS W3132

<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMS 3132</td>
<td>001/15110</td>
<td>F 1:10pm - 3:40pm</td>
<td>Jan Janak</td>
<td>4.00</td>
<td>60/60</td>
</tr>
</tbody>
</table>

COMS W3134 Data Structures in Java. 3 points.

CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: (COMS W1004) or knowledge of Java.

Data types and structures: arrays, stacks, singly and doubly linked lists, queues, trees, sets, and graphs. Programming techniques for processing such structures: sorting and searching, hashing, garbage collection.

Storage management. Rudiments of the analysis of algorithms. Taught in Java. Note: Due to significant overlap, students may receive credit for only one of the following three courses: COMS W3134, COMS W3136, COMS W3137.

Spring 2024: COMS W3134

<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMS 3134</td>
<td>001/12067</td>
<td>M W 4:10pm - 5:25pm</td>
<td>Brian Borowski</td>
<td>3</td>
<td>227/250</td>
</tr>
<tr>
<td>COMS 3134</td>
<td>002/12068</td>
<td>M W 5:40pm - 6:55pm</td>
<td>Brian Borowski</td>
<td>3</td>
<td>144/250</td>
</tr>
</tbody>
</table>

Fall 2024: COMS W3134

<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMS 3134</td>
<td>001/11932</td>
<td>M W 4:10pm - 5:25pm</td>
<td>Brian Borowski</td>
<td>3</td>
<td>147/200</td>
</tr>
<tr>
<td>COMS 3134</td>
<td>002/11933</td>
<td>M W 5:40pm - 6:55pm</td>
<td>Brian Borowski</td>
<td>3</td>
<td>86/200</td>
</tr>
</tbody>
</table>

COMS W3136 ESSENTIAL DATA STRUCTURES. 4.00 points.

Prerequisites: (COMS W1004) or (COMS W1005) or (COMS W1007) or (ENGI E1006)

A second programming course intended for nonmajors with at least one semester of introductory programming experience. Basic elements of programming in C and C++, array-based data structures, heaps, linked lists, C programming in UNIX environment, object-oriented programming in C++, trees, graphs, generic programming, hash tables. Due to significant overlap, students may only receive credit for either COMS W3134, W3136, or W3137

Fall 2024: COMS W3136

<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMS 3136</td>
<td>001/15424</td>
<td>T Th 5:40pm - 6:55pm</td>
<td>Timothy Paine</td>
<td>4.00</td>
<td>17/65</td>
</tr>
</tbody>
</table>

COMS W3137 HONORS DATA STRUCTURES & ALGOL. 4.00 points.

Prerequisites: (COMS W1004) or (COMS W1007)

Corequisites: COMS W3203

An honors introduction to data types and structures: arrays, stacks, singly and doubly linked lists, queues, trees, sets, and graphs. Programming techniques for processing such structures: sorting and searching, hashing, garbage collection. Storage management. Design and analysis of algorithms. Taught in Java. Note: Due to significant overlap, students may receive credit for only one of the following three courses: COMS W3134, W3136, or W3137
COMS W3157 ADVANCED PROGRAMMING. 4.00 points.
Lect: 4.
Prerequisites: (COMS W3134) or (COMS W3137)
C programming language and Unix systems programming. Also covers
Git, Make, TCP/IP networking basics, C fundamentals
Spring 2024: COMS W3157
<table>
<thead>
<tr>
<th>Course Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMS 3157</td>
<td>T Th 4:10pm - 5:25pm 417 International Affairs Bldg</td>
<td>Jae Lee</td>
<td>4.00</td>
<td>295/398</td>
</tr>
</tbody>
</table>

Fall 2024: COMS W3157
<table>
<thead>
<tr>
<th>Course Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMS 3157</td>
<td>T Th 4:10pm - 5:25pm 417 International Affairs Bldg</td>
<td>Jae Lee</td>
<td>4.00</td>
<td>336/398</td>
</tr>
</tbody>
</table>

COMS W3202 FINITE MATHEMATICS. 3.00 points.
COMS W3203 DISCRETE MATHEMATICS. 4.00 points.
Lect: 3.
Prerequisites: Any introductory course in computer programming.
Logic and formal proofs, sequences and summation, mathematical
induction, binomial coefficients, elements of finite probability, recurrence
relations, equivalence relations and partial orderings, and topics in graph
theory (including isomorphism, traversability, planarity, and colorings)
Spring 2024: COMS W3203
<table>
<thead>
<tr>
<th>Course Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMS 3203</td>
<td>T Th 10:10am - 11:25am 301 Urs Hall</td>
<td>Ansaf Salleb-Aouissi</td>
<td>4.00</td>
<td>215/200</td>
</tr>
<tr>
<td>COMS 3203</td>
<td>T Th 11:40am - 12:55pm 301 Urs Hall</td>
<td>Ansaf Salleb-Aouissi</td>
<td>4.00</td>
<td>207/200</td>
</tr>
</tbody>
</table>

Fall 2024: COMS W3203
<table>
<thead>
<tr>
<th>Course Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMS 3203</td>
<td>M W 4:10pm - 5:25pm 301 Pupin Laboratories</td>
<td>Tony Dear</td>
<td>4.00</td>
<td>150/270</td>
</tr>
</tbody>
</table>

COMS W3210 Scientific Computation. 3 points.
CC/GS: Partial Fulfillment of Science Requirement
Prerequisites: two terms of calculus.
Introduction to computation on digital computers. Design and analysis
of numerical algorithms. Numerical solution of equations, integration,
recurrences, chaos, differential equations. Introduction to Monte
Carlo methods. Properties of floating point arithmetic. Applications to
weather prediction, computational finance, computational science, and
computational engineering.

COMS W3251 COMPUTATIONAL LINEAR ALGEBRA. 4.00 points.
COMS W3261 COMPUTER SCIENCE THEORY. 3.00 points.
CC/GS: Partial Fulfillment of Science Requirement
Prerequisites: (COMS W3203)
Corequisites: COMS W3134,COMS W3136,COMS W3137
Regular languages: deterministic and non-deterministic finite automata,
regular expressions. Context-free languages: context-free grammars,
push-down automata. Turing machines, the Chomsky hierarchy, and
the Church-Turing thesis. Introduction to Complexity Theory and NP-
Completeness
Spring 2024: COMS W3261
<table>
<thead>
<tr>
<th>Course Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMS 3261</td>
<td>M W 2:40pm - 3:55pm 417 International Affairs Bldg</td>
<td>Josh Alman</td>
<td>3.00</td>
<td>130/150</td>
</tr>
<tr>
<td>COMS 3261</td>
<td>T Th 11:40am - 12:55pm 501 Northwest Corner</td>
<td>Mihalis Yannakakis</td>
<td>3.00</td>
<td>152/160</td>
</tr>
</tbody>
</table>

Fall 2024: COMS W3261
<table>
<thead>
<tr>
<th>Course Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMS 3261</td>
<td>T Th 8:40am - 9:55am 451 Computer Science Bldg</td>
<td>Tal Malkin</td>
<td>3.00</td>
<td>105/105</td>
</tr>
<tr>
<td>COMS 3261</td>
<td>T Th 10:10am - 11:25am 451 Computer Science Bldg</td>
<td>Tal Malkin</td>
<td>3.00</td>
<td>105/105</td>
</tr>
</tbody>
</table>

COMS W3410 COMPUTERS AND SOCIETY. 3.00 points.
Lect: 3.
Broader impact of computers. Social networks and privacy. Employment,
intellectual property, and the media. Science and engineering ethics.
Suitable for nonmajors
Fall 2024: COMS W3410
<table>
<thead>
<tr>
<th>Course Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMS 3410</td>
<td>W 4:10pm - 6:40pm 303 Uris Hall</td>
<td>Ronald Baecker</td>
<td>3.00</td>
<td>60/60</td>
</tr>
</tbody>
</table>

COMS E3899 Research Training. 0.00 points.
Research training course. Recommended in preparation for laboratory
related research
COMS W3902 UNDERGRADUATE THESIS. 0.00-6.00 points.
Prerequisites: Agreement by a faculty member to serve as thesis adviser.
An independent theoretical or experimental investigation by an
undergraduate major of an appropriate problem in computer science
carried out under the supervision of a faculty member. A formal written
report is mandatory and an oral presentation may also be required. May
be taken over more than one term, in which case the grade is deferred
until all 6 points have been completed. Consult the department for
section assignment
COMS W3995 Special Topics in Computer Science. 3 points.
Lect: 3.
Prerequisites: the instructor’s permission.
Consult the department for section assignment. Special topics arranged
as the need and availability arise. Topics are usually offered on a one-time
basis. Since the content of this course changes each time it is offered, it
may be repeated for credit.
COMS W3998 UNDERGRAD PROJECTS IN COMPUTER SCIENCE. 1.00-3.00 points.
Prerequisites: Approval by a faculty member who agrees to supervise the work.
Independent project involving laboratory work, computer programming, analytical investigation, or engineering design. May be repeated for credit. Consult the department for section assignment

COMS W3999 FIELDWORK. 1.00 point.
May be repeated for credit, but no more than 3 total points may be used toward the 128-credit degree requirement. Final report and letter of evaluation required. May not be used as a technical or non-technical elective. May not be taken for pass/fail credit or audited

COMS E3999 Fieldwork. 1 point.
Prerequisites: Obtained internship and approval from faculty advisor. May be repeated for credit, but no more than 3 total points may be used toward the 128-credit degree requirement. Only for SEAS computer science undergraduate students who include relevant off-campus work experience as part of their approved program of study. Final report and letter of evaluation required. May not be used as a technical or non-technical elective. May not be taken for pass/fail credit or audited.

COMS W4111 INTRODUCTION TO DATABASES. 3.00 points.
CC/GS: Partial Fulfillment of Science Requirement
Prerequisites: COMS W3134, COMS W3136, or COMS W3137; or the instructor’s permission.

Prerequisites: (COMS W3134) or (COMS W3136) or (COMS W3137) or The fundamentals of database design and application development using databases: entity-relationship modeling, logical design of relational databases, relational data definition and manipulation languages, SQL, XML, query processing, physical database tuning, transaction processing, security. Programming projects are required

COMS W4113 FUND-LARGE-SCALE DIST SYSTEMS. 3.00 points.
Prerequisites: (COMS W3134 or COMS W3136 or COMS W3137) and (COMS W3157 or COMS W4118 or CSEE W4119) Design and implementation of large-scale distributed and cloud systems. Teaches abstractions, design and implementation techniques that enable the building of fast, scalable, fault-tolerant distributed systems. Topics include distributed communication models (e.g. sockets, remote procedure calls, distributed shared memory), distributed synchronization (clock synchronization, logical clocks, distributed mutex), distributed file systems, replication, consistency models, fault tolerance, distributed transactions, agreement and commitment, Paxos-based consensus, MapReduce infrastructures, scalable distributed databases. Combines concepts and algorithms with descriptions of real-world implementations at Google, Facebook, Yahoo, Microsoft, LinkedIn, etc

COMS W4115 PROGRAMMING LANG # TRANSLATORS. 3.00 points.
COMS W4115 PROGRAMMING LANG # TRANSL. 3.00 points.
Lect: 3.

Prerequisites: (COMS W3134 or COMS W3136 or COMS W3137) and (COMS W2361) and (CSEE W3827) or equivalent, or the instructor’s permission.

Modern programming languages and compiler design. Imperative, object-oriented, declarative, functional, and scripting languages. Language syntax, control structures, data types, procedures and parameters, binding, scope, run-time organization, and exception handling. Implementation of language translation tools including compilers and interpreters. Lexical, syntactic and semantic analysis; code generation; introduction to code optimization. Teams implement a language and its compiler

COMS W4112 DATABASE SYSTEM IMPLEMENTATION. 3.00 points.
Lect: 2.5.

Prerequisites: (COMS W4111) and fluency in Java or C++, CSEE W3827 is recommended.
The principles and practice of building large-scale database management systems. Storage methods and indexing, query processing and optimization, materialized views, transaction processing and recovery, object-relational databases, parallel and distributed databases, performance considerations. Programming projects are required
COMS W4118 OPERATING SYSTEMS I. 3.00 points.
Lect: 3.

Prerequisites: (CSEE W3827) and knowledge of C and programming tools as covered in COMS W3136, W3157, or W3101, or the instructor’s permission.
Design and implementation of operating systems. Topics include process management, process synchronization and interprocess communication, memory management, virtual memory, interrupt handling, processor scheduling, device management, I/O, and file systems. Case study of the UNIX operating system. A programming project is required.

Spring 2024: COMS W4118

<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMS 4118</td>
<td>001/12079</td>
<td>T Th 4:10pm - 5:25pm</td>
<td>Kostis Kaffes</td>
<td>3.00</td>
<td>88/160</td>
</tr>
<tr>
<td>COMS 4118</td>
<td>V01/18798</td>
<td>501 Northwest Corner</td>
<td>Kostis Kaffes</td>
<td>3.00</td>
<td>4/99</td>
</tr>
</tbody>
</table>

COMS W4119 COMPUTER NETWORKS. 3.00 points.
Introduction to computer networks and the technical foundations of the internet, including applications, protocols, local area networks, algorithms for routing and congestion control, security, elementary performance evaluation. Several written and programming assignments required.

COMS W4121 COMPUTER SYSTEMS FOR DATA SCIENCE. 3.00 points.
Prerequisites: background in Computer System Organization and good working knowledge of C/C++
Corequisites: CSOR W4246,STAT GU4203
An introduction to computer architecture and distributed systems with an emphasis on warehouse scale computing systems. Topics will include fundamental tradeoffs in computer systems, hardware and software techniques for exploiting instruction-level parallelism, data-level parallelism and task level parallelism, scheduling, caching, prefetching, network and memory architecture, latency and throughput optimizations, specialization, and an introduction to programming data center computers.

COMS W4137 From Algorithmic Thinking to Development. 3.00 points.
Algorithmic problem-solving and coding skills needed to devise solutions to interview questions for software engineering positions. Solutions are implemented in Python, Java, C, and C++. Approaches include brute-force, hashing, sorting, transform-and-conquer, greedy, and dynamic programming. Focus on experimentation and team work.

COMS W4152 Engineering Software-as-a-Service. 3.00 points.
Modern software engineering concepts and practices including topics such as Software-as-a-Service, Service-oriented Architecture, Agile Development, Behavior-driven Development, Ruby on Rails, and Dev/ops.
COMS W4165 COMPUT TECHNIQUES-PIXEL PROCESS. 3.00 points.
An intensive introduction to image processing - digital filtering theory, image enhancement, image reconstruction, antialiasing, warping, and the state of the art in special effects. Topics from the basis of high-quality rendering in computer graphics and of low-level processing for computer vision, remote sensing, and medical imaging. Emphasizes computational techniques for implementing useful image-processing functions

COMS W4167 COMPUTER ANIMATION. 3.00 points.
Lect: 3.
Prerequisites: Multivariable calculus, linear algebra, C++ programming proficiency. COMS W4156 recommended.
Theory and practice of physics-based animation algorithms, including animated clothing, hair, smoke, water, collisions, impact, and kitchen sinks. Topics covered: Integration of ordinary differential equations, animated clothing, hair, smoke, water, collisions, impact, and kitchen sinks. Topics covered: Integration of ordinary differential equations, formulation of physical models, treatment of discontinuities including collisions/contact, animation control, constrained Lagrangian Mechanics, friction/dissipation, continuum mechanics, finite elements, rigid bodies, thin shells, discretization of Navier-Stokes equations. General education requirement: quantitative and deductive reasoning (QUA).

COMS W4170 USER INTERFACE DESIGN. 3.00 points.
CC/GS: Partial Fulfillment of Science Requirement
Prerequisites: (COMS W3134 or COMS W3136 or COMS W3137)
User interfaces. Review of relevant 3D math

COMS W4172 3D UI AND AUGMENTED REALITY. 3.00 points.
CC/GS: Partial Fulfillment of Science Requirement
Prerequisites: (COMS W4160) or (COMS W4170) or the instructor's permission.
Design, development, and evaluation of 3D user interfaces. Interaction techniques and metaphors, from desktop to immersive. Selection and manipulation. Travel and navigation. Symbolic, menu, gestural, and multimodal interaction. Dialogue design. 3D software support. 3D interaction devices and displays. Virtual and augmented reality. Tangible user interfaces. Review of relevant 3D math

COMS W4181 SECURITY I. 3.00 points.
Not offered during 2023-2024 academic year.
Prerequisites: COMS W3157 or equivalent.
Introduction to security. Threat models. Operating system security features. Vulnerabilities and tools. Firewalls, virtual private networks, viruses. Mobile and app security. Usable security. Note: May not earn credit for both W4181 and W4180 or W4187

COMS W4182 SECURITY II. 3.00 points.
Not offered during 2023-2024 academic year.
Prerequisites: COMS W4181, COMS W4118, COMS W4119
Advanced security. Centralized, distributed, and cloud system security. Cryptographic protocol design choices. Hardware and software security techniques. Security testing and fuzzing. Blockchain. Human security issues. Note: May not earn credit for both W4182 and W4180 or W4187

COMS W4186 MALWARE ANALYSIS#REVERSE ENGINEERING. 3.00 points.
Not offered during 2023-2024 academic year.
Prerequisites: COMS W3157 or equivalent. COMS W3827
COMS W4203 Graph Theory. 3 points.
Lect: 3.
Prerequisites: (COMS W3203)
General introduction to graph theory. Isomorphism testing, algebraic specification, symmetries, spanning trees, traversability, planarity, drawings on higher-order surfaces, colorings, extremal graphs, random graphs, graphical measurement, directed graphs, Burnside-Polya counting, voltage graph theory.

Spring 2024: COMS W4203
<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMS 4203</td>
<td>001/20497</td>
<td>W 7:00pm - 9:30pm 451 Computer Science Bldg</td>
<td>Yihao Zhang</td>
<td>3</td>
<td>24/60</td>
</tr>
</tbody>
</table>

COMS W4205 Combinatorial Theory. 3 points.
Lect: 3. Not offered during 2023-2024 academic year.
Prerequisites: (COMS W3203) and course in calculus. Sequences and recursions, calculus of finite differences and sums, elementary number theory, permutation group structures, binomial coefficients, Stirling numbers, harmonic numbers, generating functions.

COMS W4223 Networks, Crowds, and the Web. 3.00 points.
Introduces fundamental ideas and algorithms on networks of information collected by online services. It covers properties pervasive in large networks, dynamics of individuals that lead to large collective phenomena, mechanisms underlying the web economy, and results and tools informing societal impact of algorithms on privacy, polarization and discrimination.

Spring 2024: COMS W4223
<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMS 4223</td>
<td>001/15083</td>
<td>T Th 4:10pm - 5:25pm 833 Seeley W. Mudd Building</td>
<td>Augustin Chaintreau</td>
<td>3.00</td>
<td>69/110</td>
</tr>
<tr>
<td>COMS 4223</td>
<td>V01/18856</td>
<td></td>
<td>Augustin Chaintreau</td>
<td>3.00</td>
<td>14/99</td>
</tr>
</tbody>
</table>

COMS W4231 ANALYSIS OF ALGORITHMS I. 3.00 points.
COMS W4232 Advanced Algorithms. 3.00 points.
Prerequisite: Analysis of Algorithms (COMS W4231).
Prerequisites: see notes re: points
Introduces classic and modern algorithmic ideas that are central to many areas of Computer Science. The focus is on most powerful paradigms and techniques of how to design algorithms, and how to measure their efficiency. The intent is to be broad, covering a diversity of algorithmic techniques, rather than be deep. The covered topics have all been implemented and are widely used in industry. Topics include: hashing, sketching/streaming, nearest neighbor search, graph algorithms, spectral graph theory, linear programming, models for large-scale computation, and other related topics.

Spring 2024: COMS W4232
<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMS 4232</td>
<td>001/12084</td>
<td>M W 2:40pm - 3:55pm 633 Seeley W. Mudd Building</td>
<td>Andoni</td>
<td>3.00</td>
<td>43/100</td>
</tr>
<tr>
<td>COMS 4232</td>
<td>V01/15422</td>
<td></td>
<td>Andoni</td>
<td>3.00</td>
<td>2/99</td>
</tr>
</tbody>
</table>

COMS W4236 INTRO-COMPUTATIONAL COMPLEXITY. 3.00 points.
Lect: 3.
Prerequisites: (COMS W3261)
Develops a quantitative theory of the computational difficulty of problems in terms of the resources (e.g. time, space) needed to solve them. Classification of problems into complexity classes, reductions, and completeness. Power and limitations of different modes of computation such as nondeterminism, randomization, interaction, and parallelism.

Fall 2024: COMS W4236
<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMS 4236</td>
<td>001/11948</td>
<td>M W 8:40am - 9:55am 451 Computer Science Bldg</td>
<td>Xi Chen</td>
<td>3.00</td>
<td>52/60</td>
</tr>
<tr>
<td>COMS 4236</td>
<td>V01/17552</td>
<td></td>
<td>Xi Chen</td>
<td>3.00</td>
<td>0/99</td>
</tr>
</tbody>
</table>

COMS W4241 Numerical Algorithms and Complexity. 3 points.
Lect: 3.
Prerequisites: Knowledge of a programming language. Some knowledge of scientific computation is desirable.
Modern theory and practice of computation on digital computers. Introduction to concepts of computational complexity. Design and analysis of numerical algorithms. Applications to computational finance, computational science, and computational engineering.

COMS W4242 NUMRCL ALGORTHMS-COMPLEXITY II. 3.00 points.
COMS W4252 INTRO-COMPUTATIONAL LEARN THRY. 3.00 points.
CC/GS: Partial Fulfillment of Science Requirement
Prerequisites: (CSOR W4231) or (COMS W4236) or COMS W3203 and the instructor's permission, or COMS W3261 and the instructor's permission.
Possibilities and limitations of performing learning by computational agents. Topics include computational models of learning, polynomial time learnability, learning from examples and learning from queries to oracles. Computational and statistical limitations of learning. Applications to Boolean functions, geometric functions, automata.

COMS W4261 INTRO TO CRYPTOGRAPHY. 3.00 points.
Lect: 2.5.
Prerequisites: Comfort with basic discrete math and probability. Recommended: COMS W3261 or CSOR W4231.
An introduction to modern cryptography focusing on the complexity-theoretic foundations of secure computation and communication in adversarial environments; a rigorous approach, based on precise definitions and provably secure protocols. Topics include private and public key encryption schemes, digital signatures, authentication, pseudorandom generators and functions, one-way functions, trapdoor functions, number theory and computational hardness, identification and zero knowledge protocols.
COMS W4281 INTRO TO QUANTUM COMPUTING. 3.00 points.
Lect: 3.
Prerequisites: Knowledge of linear algebra. Prior knowledge of quantum mechanics is not required although helpful.

<table>
<thead>
<tr>
<th>Course</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMS 4281</td>
<td>001/11949</td>
<td>M W 10:10am - 11:25am</td>
<td>Henry Yuen</td>
<td>3.00</td>
<td>0/90</td>
</tr>
</tbody>
</table>

COMS W4419 INTERNET TECHNOLOGY,ECONOMICS,AND POLICY. 3.00 points.
Not offered during 2023-2024 academic year.
Technology, economic and policy aspects of the Internet. Summarizes how the Internet works technically, including protocols, standards, radio spectrum, global infrastructure and interconnection. Micro-economics with a focus on media and telecommunication economic concerns, including competition and monopolies, platforms, and behavioral economics. US constitution, freedom of speech, administrative procedures act and regulatory process, universal service, role of FCC. Not a substitute for CSEE4119. Suitable for non-majors. May not be used as a track elective for the computer science major.

COMS W4444 PROGRAMMING # PROBLEM SOLVING. 3.00 points.
CC/GS: Partial Fulfillment of Science Requirement
Prerequisites: (COMS W3134 or COMS W3136 or COMS W3137) and any
Hands-on introduction to solving open-ended computational problems. Emphasis on creativity, cooperation, and collaboration. Projects spanning a variety of areas within computer science, typically requiring the development of computer programs. Generalization of solutions to broader problems, and specialization of complex problems to make them manageable. Team-oriented projects, student presentations, and in-class participation required.

<table>
<thead>
<tr>
<th>Course</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMS 4444</td>
<td>001/11950</td>
<td>M W 1:10pm - 2:25pm</td>
<td>Kenneth Ross</td>
<td>3.00</td>
<td>0/33</td>
</tr>
</tbody>
</table>

COMS W4460 PRIN-INOVARIN/ENTREPRENEURSHIP. 3.00 points.
CC/GS: Partial Fulfillment of Science Requirement
Prerequisites: (COMS W3134 or COMS W3136 or COMS W3137) or the instructor’s permission.
Team project centered course focused on principles of planning, creating, and growing a technology venture. Topics include: identifying and analyzing opportunities created by technology paradigm shifts, designing innovative products, protecting intellectual property, engineering innovative business models.

<table>
<thead>
<tr>
<th>Course</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMS 4460</td>
<td>001/12085</td>
<td>M W 8:40am - 9:55am</td>
<td>William</td>
<td>3.00</td>
<td>34/40</td>
</tr>
<tr>
<td></td>
<td>002/12085</td>
<td>F 10:10am - 12:40pm</td>
<td>Reinsch</td>
<td>0/30</td>
<td>37/40</td>
</tr>
</tbody>
</table>

COMS W4701 ARTIFICIAL INTELLIGENCE. 3.00 points.
CC/GS: Partial Fulfillment of Science Requirement
Prerequisites: (COMS W3134 or COMS W3136 or COMS W3137) and any course on probability. Prior knowledge of Python is recommended. Prior knowledge of Python is recommended. Provides a broad understanding of the basic techniques for building intelligent computer systems. Topics include state-space problem representations, problem reduction and and-or graphs, game playing and heuristic search, predicate calculus, and resolution theorem proving. AI systems and languages for knowledge representation, machine learning and concept formation and other topics such as natural language processing may be included as time permits.

<table>
<thead>
<tr>
<th>Course</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMS 4701</td>
<td>001/12086</td>
<td>M W 2:40pm - 3:55pm</td>
<td>Tony Dear</td>
<td>3.00</td>
<td>90/164</td>
</tr>
<tr>
<td>COMS 4701</td>
<td>002/12087</td>
<td>M W 4:10pm - 5:25pm</td>
<td>Tony Dear</td>
<td>3.00</td>
<td>102/164</td>
</tr>
<tr>
<td>COMS 4701</td>
<td>V01/17158</td>
<td>F 10:10am - 11:25am</td>
<td>Tony Dear</td>
<td>3.00</td>
<td>9/99</td>
</tr>
</tbody>
</table>

COMS W4701 INTRO TO QUANTUM COMPUTING. 3.00 points.
Lect: 3.
Prerequisites: Knowledge of linear algebra. Prior knowledge of quantum mechanics is not required although helpful.

<table>
<thead>
<tr>
<th>Course</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMS 4701</td>
<td>001/11951</td>
<td>T Th 10:10am - 11:25am</td>
<td>Ansaf Salleb Aouissi</td>
<td>3.00</td>
<td>196/180</td>
</tr>
<tr>
<td>COMS 4701</td>
<td>002/11952</td>
<td>T Th 11:40am - 12:55am</td>
<td>Ansaf Salleb Aouissi</td>
<td>3.00</td>
<td>189/180</td>
</tr>
<tr>
<td>COMS 4701</td>
<td>V01/17524</td>
<td></td>
<td>Ansaf Salleb Aouissi</td>
<td>3.00</td>
<td>0/99</td>
</tr>
</tbody>
</table>
COMS W4705 NATURAL LANGUAGE PROCESSING. 3.00 points.
Lect: 3.
Prerequisites: (COMS W3134 or COMS W3136 or COMS W3137) or the instructor's permission.
Computational approaches to natural language generation and understanding. Recommended preparation: some previous or concurrent exposure to AI or Machine Learning. Topics include information extraction, summarization, machine translation, dialogue systems, and emotional speech. Particular attention is given to robust techniques that can handle understanding and generation for the large amounts of text on the Web or in other large corpora. Programming exercises in several of these areas.

COMS W4706 Spoken Language Processing. 3 points.
CC/GS: Partial Fulfillment of Science Requirement
Prerequisites: (COMS W3134 or COMS W3136 or COMS W3137) or the instructor's permission.
Computational approaches to speech generation and understanding. Techniques include speech recognition and understanding, speech analysis for computational linguistics research, and speech synthesis. Speech applications including dialogue systems, data mining, summarization, and translation. Exercises involve data analysis and building a small text-to-speech system.

COMS W4721 MACHINE LEARNING FOR DATA SCI. 3.00 points.
Spring 2024: COMS W4721
Course Number Section/Call Number Times/Location Instructor Points Enrollment
COMS 4721 001/12843 F 1:10pm - 3:40pm 501 Schermerhorn Hall Robert Kramer, 3.00 171/189
COMS 4721 001/16718 V01 Nakul Verma 3.00 2/99

COMS W4725 Knowledge representation and reasoning. 3 points.
Lect: 3. Not offered during 2023-2024 academic year.
Prerequisites: (COMS W4701)
General aspects of knowledge representation (KR). The two fundamental paradigms (semantic networks and frames) and illustrative systems. Topics include hybrid systems, time, action/plans, defaults, abduction, and case-based reasoning. Throughout the course particular attention is paid to design trade-offs between language expressiveness and reasoning complexity, and issues relating to the use of KR systems in larger applications.

COMS W4731 Computer Vision I: First Principles. 3.00 points.
Lect: 3.
Prerequisites: Fundamentals of calculus, linear algebra, and C programming. Students without any of these prerequisites are advised to contact the instructor prior to taking the course.
Introductory course in computer vision. Topics include image formation and optics, image sensing, binary images, image processing and filtering, edge extraction and boundary detection, region growing and segmentation, pattern classification methods, brightness and reflectance, shape from shading and photometric stereo, texture, binocular stereo, optical flow and motion, 2D and 3D object representation, object recognition, vision systems and applications.
COMS W4737 Biometrics. 3 points.
CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: a background at the sophomore level in computer science, engineering, or like discipline.

In this course, we will explore the latest advances in biometrics as well as the machine learning techniques behind them. Students will learn how these technologies work and how they are sometimes defeated. Grading will be based on homework assignments and a final project. There will be no midterm or final exam. This course shares lectures with COMS E6737. Students taking COMS E6737 are not allowed to earn credit for COMS W4737 or vice versa.

COMS W4762 Machine Learning for Functional Genomics. 3 points.
Prerequisites: Proficiency in a high-level programming language (Python/R/Julia). An introductory machine learning class (such as COMS 4771 Machine Learning) will be helpful but is not required.

Prerequisites: see notes re: points
This course will introduce modern probabilistic machine learning methods using applications in data analysis tasks from functional genomics, where massively-parallel sequencing is used to measure the state of cells: e.g. what genes are being expressed, what regions of DNA ("chromatin") are active ("open") or bound by specific proteins.

COMS E4762 Machine Learning for Functional Genomics. 3.00 points.
This course will introduce modern probabilistic machine learning methods using applications in data analysis tasks from functional genomics, where massively-parallel sequencing is used to measure the state of cells: e.g. what genes are being expressed, what regions of DNA ("chromatin") are active ("open") or bound by specific proteins.

COMS W4771 MACHINE LEARNING. 3.00 points.
Lect: 3.

Prerequisites: Any introductory course in linear algebra and any introductory course in statistics are both required. Highly recommended: COMS W4701 or knowledge of Artificial Intelligence.

Topics from generative and discriminative machine learning including least squares methods, support vector machines, kernel methods, neural networks, Gaussian distributions, linear classification, linear regression, maximum likelihood, exponential family distributions, Bayesian networks, Bayesian inference, mixture models, the EM algorithm, graphical models and hidden Markov models. Algorithms implemented in MATLAB.

COMS W4772 ADVANCED MACHINE LEARNING. 3.00 points.
Lect: 3.

Prerequisites: (COMS W4771) or instructor’s permission; knowledge of linear algebra & introductory probability or statistics is required.

An exploration of advanced machine learning tools for perception and behavior learning. How can machines perceive, learn from, and classify human activity computationally? Topics include appearance-based models, principal and independent components analysis, dimensionality reduction, kernel methods, manifold learning, latent models, regression, classification, Bayesian methods, maximum entropy methods, real-time tracking, extended Kalman filters, time series prediction, hidden Markov models, factorial HMMs, input-output HMMs, Markov random fields, variational methods, dynamic Bayesian networks, and Gaussian/Dirichlet processes. Links to cognitive science.

COMS W4773 Machine Learning Theory. 3 points.
Prerequisites: Machine Learning (COMS W4771). Background in probability and statistics, linear algebra, and multivariate calculus. Ability to program in a high-level language, and familiarity with basic algorithm design and coding principles.

Prerequisites: see notes re: points
Core topics from unsupervised learning such as clustering, dimensionality reduction and density estimation will be studied in detail. Topics in clustering: k-means clustering, hierarchical clustering, spectral clustering, clustering with various forms of feedback, good initialization techniques and convergence analysis of various clustering procedures. Topics in dimensionality reduction: linear techniques such as PCA, ICA, Factor Analysis, Random Projections, non-linear techniques such as LLE, IsoMap, Laplacian Eigenmaps, TSNE, and study of embeddings of general metric spaces, what sorts of theoretical guarantees can one provide about such techniques. Miscellaneous topics: design and analysis of data structures for fast Nearest Neighbor search such as Cover Trees and LSH. Algorithms will be implemented in either Matlab or Python.
COMS E4773 Machine Learning Theory. 3.00 points.
Theoretical study of algorithms for machine learning and high-dimensional data analysis. Topics include high-dimensional probability, theory of generalization and statistical learning, online learning and optimization, spectral analysis

<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMS 4773</td>
<td>001/12094</td>
<td>T Th 8:40am - 9:55am</td>
<td>Daniel Hsu</td>
<td>3.00</td>
<td>34/60</td>
</tr>
</tbody>
</table>

COMS W4774 Unsupervised Learning. 3.00 points.
Prerequisites: Solid background in multivariate calculus, linear algebra, basic probability, and algorithms.

Prerequisites: see notes re: points
Core topics from unsupervised learning such as clustering, dimensionality reduction and density estimation will be studied in detail. Topics in clustering: k-means clustering, hierarchical clustering, spectral clustering, clustering with various forms of feedback, good initialization techniques and convergence analysis of various clustering procedures. Topics in dimensionality reduction: linear techniques such as PCA, ICA, Factor Analysis, Random Projections, non-linear techniques such as LLE, IsoMap, Laplacian Eigenmaps, TSNE, and study of embeddings of general metric spaces, what sorts of theoretical guarantees can one provide about such techniques. Miscellaneous topics: design and analysis of data structures for fast Nearest Neighbor search such as Cover Trees and LSH. Algorithms will be implemented in either Matlab or Python

<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMS 4774</td>
<td>001/11958</td>
<td>T Th 1:10pm - 2:25pm</td>
<td>Nakul Verma</td>
<td>3.00</td>
<td>8/50</td>
</tr>
</tbody>
</table>

COMS W4775 Causal Inference. 3.00 points.
Prerequisites: Discrete Math, Calculus, Statistics (basic probability, modeling, experimental design), some programming experience.

Prerequisites: see notes re: points
Causal Inference theory and applications. The theoretical topics include the 3-layer causal hierarchy, causal bayesian networks, structural learning, the identification problem and the do-calculus, linear identifiability, bounding, and counterfactual analysis. The applied part includes intersection with statistics, the empirical-data sciences (social and health), and AI and ML

<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMS 4775</td>
<td>001/11959</td>
<td>M W 4:10pm - 5:25pm</td>
<td>Elias Bareinboim</td>
<td>3.00</td>
<td>27/50</td>
</tr>
</tbody>
</table>

COMS E4775 Causal Inference. 3 points.
Prerequisites: (COMS4711W) and Discrete Math, Calculus, Statistics (basic probability, modeling, experimental design), Some programming experience
Causal Inference theory and applications. The theoretical topics include the 3-layer causal hierarchy, causal bayesian networks, structural learning, the identification problem and the do-calculus, linear identifiability, bounding, and counterfactual analysis. The applied part includes intersection with statistics, the empirical-data sciences (social and health), and AI and ML.
COMS W4995 TOPICS IN COMPUTER SCIENCE. 3.00 points. 
Lect: 3.
Prerequisites: Instructor’s permission.
Selected topics in computer science. Content and prerequisites vary between sections and semesters. May be repeated for credit. Check "topics course" webpage on the department website for more information on each section.

Spring 2024: COMS W4995

<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMS 4995</td>
<td>001/12095</td>
<td>T Th 8:40am - 9:55am</td>
<td>Andrew Blumberg</td>
<td>3.00</td>
<td>26/40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1024 Seeley W. Mudd Building</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COMS 4995</td>
<td>002/12096</td>
<td>M W 5:40pm - 5:55pm</td>
<td>Yongwhan Lim</td>
<td>3.00</td>
<td>11/50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1024 Seeley W. Mudd Building</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COMS 4995</td>
<td>003/12098</td>
<td>Th 4:10pm - 5:40pm</td>
<td>Christian Swinhart</td>
<td>3.00</td>
<td>33/40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1127 Seeley W. Mudd Building</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COMS 4995</td>
<td>004/12099</td>
<td>Th 5:40pm - 5:55pm</td>
<td>Austin Reiter</td>
<td>3.00</td>
<td>95/110</td>
</tr>
<tr>
<td></td>
<td></td>
<td>451 Computer Science Bldg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COMS 4995</td>
<td>005/12101</td>
<td>F 10:10am - 12:40pm</td>
<td>Michelle Levine</td>
<td>3.00</td>
<td>24/40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1127 Seeley W. Mudd Building</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COMS 4995</td>
<td>006/12102</td>
<td>T 1:10pm - 3:40pm</td>
<td>Gary Zamchick</td>
<td>3.00</td>
<td>39/40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1127 Seeley W. Mudd Building</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COMS 4995</td>
<td>008/12104</td>
<td>W 4:10pm - 5:40pm</td>
<td>Hans Montero, Jae Lee</td>
<td>3.00</td>
<td>74/110</td>
</tr>
<tr>
<td></td>
<td></td>
<td>451 Computer Science Bldg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COMS 4995</td>
<td>030/12956</td>
<td>W 7:00pm - 9:30pm</td>
<td>Adam Kelleher</td>
<td>3.00</td>
<td>63/70</td>
</tr>
<tr>
<td></td>
<td></td>
<td>413 Kent Hall</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COMS 4995</td>
<td>032/12965</td>
<td>W 4:10pm - 6:40pm</td>
<td>Vijay Pappu</td>
<td>3.00</td>
<td>101/100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>329 Pupin Laboratories</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COMS 4995</td>
<td>001/18718</td>
<td>W 4:10pm - 6:40pm</td>
<td>Andrew Blumberg</td>
<td>3.00</td>
<td>0/99</td>
</tr>
<tr>
<td></td>
<td></td>
<td>451 Computer Science Bldg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COMS 4995</td>
<td>002/15425</td>
<td>W 4:10pm - 6:40pm</td>
<td>Yongwhan Lim</td>
<td>3.00</td>
<td>0/99</td>
</tr>
<tr>
<td></td>
<td></td>
<td>301 Pupin Laboratories</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COMS 4995</td>
<td>008/16721</td>
<td>W 4:10pm - 6:40pm</td>
<td>Jae Lee, Hans Montero</td>
<td>3.00</td>
<td>2/99</td>
</tr>
<tr>
<td></td>
<td></td>
<td>451 Computer Science Bldg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COMS 4995</td>
<td>032/20861</td>
<td>W 4:10pm - 6:40pm</td>
<td>Vijay Pappu</td>
<td>3.00</td>
<td>20/99</td>
</tr>
<tr>
<td></td>
<td></td>
<td>207 Mathematics Building</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

COMS W4996 Special topics in computer science, II. 3.00 points. 
Lect: 3. Not offered during 2023-2024 academic year.
Prerequisites: Instructor’s permission.
A continuation of COMS W4995 when the special topic extends over two terms.

Computer Science - Electrical Engineering

CSEE W3826 FUNDAMENTALS OF COMPUTER ORG. 3.00 points.

CSEE W3827 FUNDAMENTALS OF COMPUTER SYSTS. 3.00 points.
Lect: 3.
Prerequisites: an introductory programming course. Fundamentals of computer organization and digital logic. Boolean algebra, Karnaugh maps, basic gates and components, flipflops and latches, counters and state machines, basics of combinational and sequential digital design. Assembly language, instruction sets, ALU’s, single-cycle and multi-cycle processor design, introduction to pipelined processors, caches, and virtual memory.

Spring 2024: CSEE W3827

<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSEE 3827</td>
<td>001/12121</td>
<td>T Th 10:10am - 11:25am</td>
<td>Daniel Rubenstein</td>
<td>3.00</td>
<td>134/152</td>
</tr>
<tr>
<td></td>
<td></td>
<td>207 Mathematics Building</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CSEE 3827</td>
<td>002/12122</td>
<td>T Th 11:40am - 12:55pm</td>
<td>Daniel Rubenstein</td>
<td>3.00</td>
<td>136/147</td>
</tr>
<tr>
<td></td>
<td></td>
<td>428 Pupin Laboratories</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fall 2024: CSEE W3827

<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSEE 3827</td>
<td>001/11985</td>
<td>T Th 11:40am - 12:55pm</td>
<td>Martha Kim, Martha Barker</td>
<td>3.00</td>
<td>164/164</td>
</tr>
<tr>
<td></td>
<td></td>
<td>301 Pupin Laboratories</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CSEE 3827</td>
<td>002/11986</td>
<td>T Th 1:10pm - 2:25pm</td>
<td>Martha Kim, Martha Barker</td>
<td>3.00</td>
<td>159/164</td>
</tr>
<tr>
<td></td>
<td></td>
<td>301 Pupin Laboratories</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CSEE 3827</td>
<td>004/11987</td>
<td>M W 1:10pm - 2:15pm</td>
<td>Stephen Edwards</td>
<td>3.00</td>
<td>37/70</td>
</tr>
<tr>
<td></td>
<td></td>
<td>622.004/207 Mathematics Building</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CSEE 3827</td>
<td>005/11988</td>
<td>T Th 1:10pm - 2:25pm</td>
<td>Peter Bellum</td>
<td>3.00</td>
<td>98/125</td>
</tr>
<tr>
<td></td>
<td></td>
<td>451 Computer Science Bldg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CSEE 3827</td>
<td>006/11989</td>
<td>M W 1:10pm - 2:15pm</td>
<td>Paul Blamer, Jason Cahl</td>
<td>3.00</td>
<td>0/40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>829 Seeley W. Mudd Building</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CSEE 3827</td>
<td>007/11990</td>
<td>Th 2:10pm - 3:25pm</td>
<td>Gary Zimdick</td>
<td>3.00</td>
<td>0/110</td>
</tr>
<tr>
<td></td>
<td></td>
<td>833 Seeley W. Mudd Building</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CSEE 3827</td>
<td>008/11991</td>
<td>T Th 1:10pm - 2:15pm</td>
<td>Xia Zhou</td>
<td>3.00</td>
<td>6/99</td>
</tr>
<tr>
<td></td>
<td></td>
<td>829 Seeley W. Mudd Building</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CSEE 3827</td>
<td>009/11992</td>
<td>M W 1:10pm - 2:15pm</td>
<td>Michelle Levine</td>
<td>3.00</td>
<td>0/40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>833 Seeley W. Mudd Building</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CSEE 3827</td>
<td>010/11993</td>
<td>Th 2:10pm - 3:25pm</td>
<td>Homayoun Beig</td>
<td>3.00</td>
<td>21/60</td>
</tr>
<tr>
<td></td>
<td></td>
<td>833 Seeley W. Mudd Building</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CSEE 3827</td>
<td>011/11994</td>
<td>T Th 2:10pm - 3:25pm</td>
<td>Hugh Thomas</td>
<td>3.00</td>
<td>50/100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>451 Computer Science Bldg</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CSEE W4121 COMPUTER SYSTEMS FOR DATA SCIENCE. 3.00 points.
Prerequisites: Background in Computer System Organization and good working knowledge of C/C++. Corequisites: CSOR W4246 Algorithms for Data Science, STAT W4203 Probability Theory, or equivalent as approved by faculty advisor.
An introduction to computer architecture and distributed systems with an emphasis on warehouse scale computing systems. Topics will include fundamental tradeoffs in computer systems, hardware and software techniques for exploiting instruction-level parallelism, data-level parallelism and task level parallelism, scheduling, caching, prefetching, network and memory architecture, latency and throughput optimizations, specialization, and an introduction to programming data center computers.

Spring 2024: CSEE W4121
Course Number: 4121
Section/Call Number: 002/12974
Times/Location: Th 7:00pm - 9:30pm
Instructor: Sambit Sahu
Points: 3.00
Enrollment: 178/175

CSEE W4140 NETWORKING LABORATORY. 3.00 points.
Lect: 3.
Prerequisites: (CSEE W4119) or equivalent.
In this course, students will learn how to put principles into practice, in a hands-on networking lab course. The course will cover the technologies and protocols of the Internet using equipment currently available to large internet service providers such as CISCO routers and end systems. A set of laboratory experiments will provide hands-on experience with engineering wide-area networks and will familiarize students with the Internet Protocol (IP), Address Resolution Protocol (ARP), Internet Control Message Protocol (ICMP), User Datagram Protocol (UDP) and Transmission Control Protocol (TCP), the Domain Name System (DNS), routing protocols (RIP, OSPF, BGP), network management protocols (SNMP, and application-level protocols (FTP, TELNET, SMTP)

CSEE W4823 Advanced Logic Design. 3 points.
Lect: 3.
Prerequisites: (CSEE W3827) or a half semester introduction to digital logic, or the equivalent.
An introduction to modern digital system design. Advanced topics in digital logic: controller synthesis (Mealy and Moore machines); adders and multipliers; structured logic blocks (PLDs, PALs, ROMs); iterative circuits. Modern design methodology: register transfer level modelling (RTL); algorithmic state machines (ASMs); introduction to hardware description languages (VHDL or Verilog); system-level modelling and simulation; design examples.

Fall 2024: CSEE W4823
Course Number: 4823
Section/Call Number: 001/11307
Times/Location: T Th 2:40pm - 3:55pm
Instructor: Mingoo Seok
Points: 3
Enrollment: 73/120

CSEE W4824 COMPUTER ARCHITECTURE. 3.00 points.
Lect: 3.
Prerequisites: (CSEE W3827) or equivalent.

Fall 2024: CSEE W4824
Course Number: 4824
Section/Call Number: 001/11987
Times/Location: M W 10:10am - 11:25am
Instructor: Sethumadhavan
Points: 3.00
Enrollment: 61/55

CSEE W4840 EMBEDDED SYSTEMS. 3.00 points.
Lect: 3.
Prerequisites: (CSEE W4823)
Embedded system design and implementation combining hardware and software. I/O, interfacing, and peripherals. Weekly laboratory sessions and term project on design of a microprocessor-based embedded system including at least one custom peripheral. Knowledge of C programming and digital logic required.

Spring 2024: CSEE W4840
Course Number: 4840
Section/Call Number: 001/12033
Times/Location: M W 10:10am - 11:25am
Instructor: Sethumadhavan
Points: 3.00
Enrollment: 97/110

CSEE W4868 SYSTEM-ON-CHIP PLATFORMS. 3.00 points.
Prerequisites: (COMS W3157) and (CSEE W3827)
Design and programming of System-on-Chip (SoC) platforms. Topics include: overview of technology and economic trends, methodologies and supporting CAD tools for system-level design, models of computation, the SystemC language, transaction-level modeling, software simulation and virtual platforms, hardware-software partitioning, high-level synthesis, system programming and device drivers, on-chip communication, memory organization, power management and optimization, integration of programmable processor cores and specialized accelerators. Case studies of modern SoC platforms for various classes of applications.

Fall 2024: CSEE W4868
Course Number: 4868
Section/Call Number: 001/11988
Times/Location: T Th 11:40am - 12:55pm
Instructor: Luca Carloni
Points: 3.00
Enrollment: 43/60
Computer Science - Biomedical Engineering

CBMF W4761 COMPUTATIONAL GENOMICS. 3.00 points.
Lect: 3.

Prerequisites: Working knowledge of at least one programming language, and some background in probability and statistics.
Computational techniques for analyzing genomic data including DNA, RNA, protein and gene expression data. Basic concepts in molecular biology relevant to these analyses. Emphasis on techniques from artificial intelligence and machine learning. String-matching algorithms, dynamic programming, hidden Markov models, expectation-maximization, neural networks, clustering algorithms, support vector machines. Students with life sciences backgrounds who satisfy the prerequisites are encouraged to enroll.

Spring 2024: CBMF W4761

<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBMF 4761</td>
<td>001/12050</td>
<td>M W 5:40pm - 6:55pm, 1127 Seeley W. Mudd Building</td>
<td>Itsik Pe'er</td>
<td>3.00</td>
<td>32/60</td>
</tr>
<tr>
<td>CBMF 4761</td>
<td>V01/15241</td>
<td></td>
<td>Itsik Pe'er</td>
<td>3.00</td>
<td>1/99</td>
</tr>
</tbody>
</table>