

# Master Programme in Computer Science

The aim of the Master's programme is to provide a broad education in Computer Science with the possibility of deepening and specializing within the area of computer science, the method science for construction of computer programs including theoretical foundations as well as the practical ability to develop products and systems which include computers and software.

The programme will provide the students with the requisites and abilities to participate and lead work within evaluation, development and implementation of new technology within the field of computer science.

## Overall structure

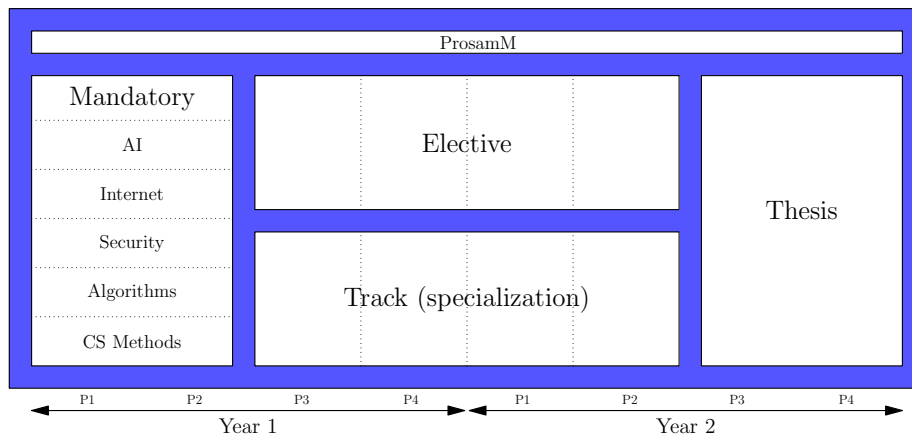


Figure 1: Overall structure of the programme.

## Mandatory Courses

The main role of the mandatory courses in the programme is to ensure that all students have a broad knowledge in the field of computer science.

- Regular courses
  - DD2440 Advanced Algorithms, 6 credits
  - DD2395 Computer Security, 6 credits
  - IK2218 Protocols and Principles of the Internet, 6 credits
  - DD2380 Artificial Intelligence, 6 credits
- Scientific methodology
  - DA2210 Introduction to the Philosophy of Science and Research Methodology for Computer Scientists, 6 credits
- Integrating
  - DD2300 Program Integrating Course in Computer Science, 2 credits
  - DA221X/DA222X Degree Project in Computer Science and Communication, 30 credits

## Tracks

The main role of the tracks is to ensure that every student has a deepened knowledge in one part of computer science. All tracks offered are connected to local faculty active in research.

The tracks start in the spring semester of the first year, and continues in the autumn of year two. The track is composed of separate courses which totals to 30 credit points. In parallel with the track courses, the students take their elective courses.

Some of the tracks offer a choice of courses within the track to make it possible to focus even more within the subject of the track.

## Learning outcomes common for all tracks

- *Knowledge and Understanding*

After passing the track, the student should

- demonstrate knowledge about the scientific basis and established procedures in computer science, as well as a insights into current research and development work,
- demonstrate substantially deeper knowledge in the topic of the track.

- *Skills and Abilities*

After passing the track, the student should

- demonstrate an ability to critically, independently and creatively identify, formulate and handle complex objectives and to participate in reseach and development work and thereby contribute to the creation of new knowledge,

- demonstrate an ability to create, analyze and critically evaluate different technical solutions,
  - demonstrate an ability to plan and, using appropriate methods, carry out advanced tasks,
  - demonstrate an ability to critically and systematically integrate knowledge,
  - demonstrate an ability to develop and design products, processes and systems with consideration of users and society.
- *Judgement and Approach*

After passing the track, the student should

- demonstrate an ability to make judgements and decisions based on relevant scientific aspects as well as demonstrating awareness of ethical aspects on research and development work.

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## Track CSCS: Cognitive Systems

This track is about the development of programs displaying artificial intelligence, i.e. abilities normally associated with humans. Within this track it is possible to further specialize towards computer vision and robotics or towards conversational systems.

**Faculty:** Gabriel Skantze (coordinator), Jonas Beskow, Johan Boye, Patric Jensfelt, John Folkesson

### Prerequisites:

- SD1626 Multivariate Calculus, 7.5 credits (or equivalent)

### Mandatory courses

- DD2421 Machine Learning, 7.5 credits y1p3

### Subtrack - Vision and Robotics

- DD2424 Deep Learning in Data Science, 7.5 credits y1p4
- DD2423 Image Analysis and Computer Vision, 7.5 credits y2p2
- DD2425 Robotics and Autonomous Systems, 9.0 credits y2p1-2

## Subtrack - Conversational Systems

- DT2140 Multimodal Interaction and Interfaces, 7.5 credits y2p2
- DT2nnn Project in Cognitive Systems, 9 credits **NEW**
- At least one of:
  - DT2112 Speech technology, 7.5 credits y1p3
  - DT2119 Speech and Speaker Recognition, 7.5 credits y1p4

## Recommended elective courses

- DD2418 Language Engineering, 6.0 credits
- DD2427 Image Based Recognition and Classification, 6 credits
- DD2429 Computational Photography, 6.0 credits
- DD2434 Machine Learning, Advanced Course, 7.5 credits
- DD2437 Artificial Neural Networks, 7.5 credits
- DD2438 Artificial Intelligence and Multi Agent Systems
- DD2447 Statistical Methods in Applied Computer Science 6.0 credits
- DD2476 Search Engines and Information Retrieval Systems, 9.0 credits
- EL2320 Applied Estimation, 7.5 credits
- EN2202 Pattern Recognition 7.5 credits
- DT1130 Spectral Transforms, 7.5 credits
- DT2350 Human Perception for Information Technology, 6.0 credits
- DT2410 Audio Technology, 7.5 credits
- SF1840 Optimization, 6.0 credits
- SF2862 Stochastic Decision Support Models, 7.5 credits
- SF2940 Probability Theory 7.5 credits

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## Track CSDA: Data Science

Our society is producing an enormous amount of data. This track is about methods to handle and analyze data from different sources, such as biological sequence data, images and video, text, etc.

**Faculty:** John Folkesson (coordinator), Hedvig Kjellström, Jens Lagergren, Erwin Laure, Atsuto Maki, Josephine Sullivan, Lars Arvestad, Johan Boye, Stefan Carlsson, Johan Hoffman, Viggo Kann, Jussi Karlgren, Pawel Herman, Jeanette Hellgren Kotaleski, Carl Henrik Ek

### Prerequisites:

- SD1626 Multivariate Calculus, 7.5 credits (or equivalent)

## Mandatory courses

- DD2421 Machine Learning, 7.5 credits y1p3
- DD2nnn Data Science, Project Course, 9 credits y2p2 **NEW**

## Subtrack - Machine Learning

- DD2424 Deep Learning in Data Science, 7.5 credits y1p4
- DD2434 Machine Learning, Advanced Course, 7.5 credits y2p2

## Subtrack - Natural Language Processing

- DD2476 Search Engines and Information Retrieval Systems, 9.0 credits y1p3-4
- DD2418 Language Engineering, 6.0 credits y2p2

## Subtrack - Bioinformatics

- SF2940 Probability Theory 7.5 credits y2p1
- DD2404 Applied Bioinformatics, 7.5 credits y2p2

## Recommended elective courses

We firstly recommend picking courses from the subtracks other than the one you are following. Apart from them, the following courses are of interest:

- Year 1
  - DD2438 Artificial Intelligence and Multi Agent Systems, 15.0 credits
  - DD2450 Algorithmic Bioinformatics, 6.0 credits
  - DH2320 Introduction to Visualization and Computer Graphics, 6.0 credits
  - DH2321 Information Visualization, 6.0 credits
  - DT2112 Speech technology, 7.5 credits
  - DT2118 Speech and Speaker Recognition, 7.5 credits
- Year 2
  - DD2423 Image Analysis and Computer Vision, 7.5 credits
  - DD2425 Robotics and Autonomous Systems, 9.0 credits
  - DD2429 Computational Photography, 6.0 credits
  - DD2447 Statistical Methods in Applied Computer Science, 6.0 credits
  - DD2257 Visualization, 7.5 credits
  - EL2320 Applied Estimation, 7.5 credits

– SF1811 Optimization, 6.0 credits

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## Track CSID: Interaction Design

The students learn how to develop interactive systems using modern development techniques. The track will also give a deeper knowledge in how to systematically evaluate interactive systems.

**Faculty:** Ylva Fernaeus (coordinator), Cristian Bogdan, Lotta Sallnäs Pysander, Kia Höök, Jarmo Laaksolahti

### Mandatory courses

- DH2628 Interaction Design Methods, 7.5 credits y1p3
- DH2629 Interaction Design as Reflective Practice, 7.5 credits y1p4
- DH2627 Interaktion Design 2, 15 credits y2p1-2

### Recommended elective courses

- DH2408 Utvärderingsmetoder inom människa-datorinteraktion, 6 credits
  - DH2632 Higher seminars in Human-Computer Interaction, 3 credits
  - DH2641 Interaktionsprogrammering, 6 credits
  - DH2400 Physical Interaction design and realisation, 7.5 credits
  - DT2140 Multimodala interaktioner och gränssnitt, 7.5 credits
  - DH2321 Information Visualization, 6 credits
  - DH2413 Advanced Graphics and Interaction, 9 credits
  - DM2518 Mobilutveckling med webbt teknologier 7.5 credits
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## Track CSSC: Scientific Computing

This track is about techniques for mathematical modeling and numerical simulation of physical, chemical or biological systems. This is the basis for doing virtual experiments, such as simulated car crashes, but also for building interactive virtual environments, for example for computer games.

This track also gives the students both practical and theoretical knowledge about how to use modern supercomputers for high performance computations. Focus is on parallel algorithms, but we also touch upon brain-inspired algorithms and usage of special purpose hardware, such as GPU-processors.

**Faculty:** Johan Hoffman (coordinator), Erik Fransén, Pawel Herman, Johan Jansson, Arvind Kumar, Erwin Laure, Stefano Markidis, Christopher Peters, Tino Weinkauff

**Prerequisites:**

- SD1626 Multivariate Calculus, 7.5 credits (or equivalent)

**Mandatory courses**

- DD2363 Methods in Scientific Computing, 7.5 credits y1p3
- DD2356 Methods in High Performance Computing, 7.5 credits y1p4
- DD2444 Project Course in Scientific Computing, 7.5 credits y2p2

**Conditionally elective courses**

*Condition:* Minimum of one course from this list

- DD2437 Artificial neural networks, 7.5 credits y1p3
- DD2257 Visualization, 7.5 credits y2p1
- DD2365 Advanced computation in fluid mechanics, 7.5 credits y1p4

**Recommended elective courses**

- DH2320 Introduction to Visualization and Computer Graphics, 6 credits y1p3
- DD2443 Parallel and distributed computing, 7.5 credits y1p3
- HL2008 Simulation Methods in Medical Engineering, 7.5 credits y1p3
- DT2212 Music Acoustics, 7.5 credits y1p3
- DD2401 Neuroscience, 7.5 credits y1p4
- DD2421 Machine learning, 7.5 credits y1p3 or y2p1
- DD2435 Mathematical modelling of biological systems, 9 credits y2p1-2
- SF2561 The finite element method, 7.5 credits, y2p1
- SF2565 Software engineering in C++ for scientific computing, 7.5 credits y2p1-2
- EL2820 Modelling of dynamical systems, 7.5 credits y2p1
- DD2402 Applied Bioinformatics, 7.5 credits y2p2
- BB2280 Molecular modeling, 7.5 credits y2p2

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**Track CSST: Software Technology**

This track is about methods for designing, developing and maintaining software.

**Faculty:** Philipp Haller (coordinator), Mads Dam, Karl Meinke, Sonja Buchegger, Michael Minock

## Mandatory courses

- DD2480 Software Engineering Fundamentals, 7.5 credits y1p3

## Subtrack - Computer Security

- DD2448 Foundations of Cryptography, 7.5 credits y1p3-4
- DD2nnn System Security (project course), 7.5 credits **NEW**
- At least one of:
  - DD2460 Software Safety and Security, 7.5 credits y1p4
  - DD2496 Privacy-Enhancing Tech., 7.5 credits y2p1

## Subtrack - Programming Languages

- DD2481 Principles of Programming Languages, 7.5 credits y1p4
- DD2488 Compiler Construction, 9 credits y2p1-2
- At least one of:
  - DD2451 Parallel and Distr. Computing, 6 credits **Discontinued**
  - DD2457 Program Semantics and. . . , 6 credits y1p4
  - DD2471 Modern DB Systems and. . . , 7.5 credits **Cancelled**
  - DD2372 Automata and Languages, 6 credits y1p4

## Subtrack - Software Engineering

- DD2459 Software Reliability, 7.5 credits y1p3
- DD2386 Patterns for Large-Scale Development, 7.5 credits y2p2
- At least one of:
  - DD2460 Software Safety and Security, 7.5 credits y1p4
  - DD2471 Modern DB Systems and. . . , 7.5 credits **Cancelled**
  - DD2481 Princ. Prog. Languages, 7.5 credits y1p4

## Recommended elective courses

- DD2390 Internet programming, 6 hp
- DD2451 Parallel and Distributed Computing, 6 hp
- DD2471 Modern Database Systems and Their Applications, 7.5 hp
- DD2476 Search Engines and Information Retrieval Systems, 9 hp
- DD2421 Machine learning, 7.5 credits y1p3 or y2p1



- DD2458 Programming and problem solving under pressure, 9 hp (limited to 30 students)
- ID1217 Concurrent Programming, 7.5 hp

For computer security:

- EP2500 Networked Systems Security, 7.5 hp
- EP2510 Advanced Networked Systems Security, 7.5 hp
- EP2520 Building Networked Systems Security, 7.5 hp

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## Track CSTC: Theoretical Computer Science

Theoretical computer science is the study of abstract or mathematical aspects of computing. Work in this field is often distinguished by its emphasis on mathematical technique and rigor.

**Faculty:** Per Austrin (coordinator), Dilian Gurov, Johan Håstad, Danupon Nanongkai, Jakob Nordström, Douglas Wikström

### Mandatory courses

- DD2467 Individual Project in Theoretical Computer Science, 7.5 credits
- At least one of:
  - SF2713 Foundations of Analysis
  - SF2723 Topics in Mathematics III
  - SF2724 Topics in Mathematics IV
  - SF2729 Groups and Rings
  - SF2730 Topics in Mathematics V
  - SF2741 Enumerative Combinatorics
  - SF2940 Probability Theory
  - SF2955 Computer Intensive Methods in Mathematical Statistics
  - SF2972 Game Theory

### Subtrack - Algorithms, Complexity and Cryptography

- DD2448 Foundations of Cryptography, 7.5 credits y1p3-4
- At least one of:
  - DD2445 Complexity Theory, 7.5 credits y2p1-2
  - DD2442 Seminars on Theoretical Computer Science, 7.5 credits y2p1-2

## Subtrack - Formal Methods and Semantics

- DD2452 Formal Methods, 7.5 credits **Not scheduled**
- At least one of:
  - DD2372 Automata and Languages, 6 credits y1p4
  - DD2442 Seminars on Theoretical Computer Science, 7.5 credits y2p1-2
  - DD2443 Parallel and Distributed Computing, 7.5 credits y1p3
  - DD2445 Complexity Theory, 7.5 credits y2p1-2
  - DD2448 Foundations of Cryptography, 7.5 credits y1p3-4
  - DD2457 Program Semantics and Analysis, 6 credits y1p4
  - DD2459 Software Reliability 7.5 credits y1p3
  - DD2460 Software Safety and Security, 7.5 credits y1p4

## Recommended elective courses

Courses in more or less every field of mathematics, e.g., combinatorics, analysis, probability theory, optimization, logic, group theory, algebra, etc.

- DD2447 Statistical Methods in Computer Science, 6 credits
- DD2450 Algorithmic Bioinformatics, 6 credits
- DD2451 Parallel and Distributed Computing, 6 credits
- DD2458 Programming and problem solving under pressure, 9 credits (limited to 30 students)
- ID1217 Concurrent Programming, 7.5 credits

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## Track CSVG: Visualization and Interactive Graphics

With the growing amount of digital information, the need for understanding this data increases as well. Visualization strives to convey information via the human sense with the largest bandwidth, namely the visual system. Hence, it aids the process of understanding data by intelligently filtering and mapping data into a visual form.

One major technical basis for this is Computer Graphics. Graphics is not only a basis for visualization, but finds its applications also in computer games, virtual and augmented reality, industrial design, cultural heritage, and other growing areas in research and industry.

This track spans from the basics of visualization and graphics to recent research topics. It consists of courses that provide a mix of theoretical knowledge and practical expertise. Programming is an integral part of this track.

**Faculty:** Tino Weinkauff (coordinator), Mario Romero, Christopher Peters, Björn Thuresson, Roberto Bresin, Mårten Björkman

### **Mandatory courses**

- DH2320 Introduction to Visualization and Computer Graphics, 6 credits y1p3
- DDnmmn Advanced Topics in Visualization and Computer Graphics, 6 credits y2p2 **NEW**

### **Conditionally elective courses**

*Condition:* Minimum a total of 18 credits from this list

- DH2321 Information Visualization, 6 credits y1p3
- DD2257 Visualization, 7.5 credits y2p1
- DH2323 Computer Graphics and Interaction, 6 credits y1p4
- DH2413 Advanced Graphics and Interaction, 9 credits y2p1-2
- DH2650 Computer Game Design, 6 credits y2p2

### **Recommended elective courses**

- DD2424 Deep Learning in Data Science, 7.5 credits
- DD2356 Methods in High Performance Computing, 7.5 credits
- DT2350 Human Perception for Information Technology, 6 credits
- DD2429 Computational Photography, 6.0 credits
- DD2423 Image Analysis and Computer Vision, 7.5 credits