Programme syllabus

Master's Programme, Machine Learning, 120 credits
Masterprogram, maskininläerning

120.0 credits

Valid for students admitted to the education from autumn 14 (HT - Autumn term; VT - Spring term).

This is a translation of the Swedish, legally binding, programme syllabus.

Programme objectives

This programme syllabus, decided by the CSC dean 2013-09-27 is valid for students starting the programme during the study year 2014/2015. Which courses that belong to a study year is decided in the fall the year before. Please see ”Study year 1” etc. or the appendices. Changes may occur in the contents of the programme and in the KTH regulations, please see www.kth.se/en/student.

Machine Learning is an area within Computer Science where computer systems are designed to learn from large sets of examples, similarly to the learning strategies of biological systems (like humans). Recently, Machine Learning has gained great importance for the design of search engines, robots, and sensor systems, and for the processing of large scientific data sets.

The focus of the Master’s programme in Machine Learning is on mathematical foundations and methods for Machine Learning. The student can choose to study applications of this in Perception and Cognition or in Information Retrieval. For a closer description of the two tracks, see Appendix 2.

Besides the goals stated in the Swedish Higher Education Ordinance the following goals apply. Link to goals stated in the Swedish Higher Education Ordinance: http://www.csc.kth.se/utbildning/dokument/HSVmal/hsvmastereng.pdf

Knowledge and understanding

A Master of Science in Machine Learning will be able to:

- present a good knowledge of mathematical methods for Machine Learning, as well as how these are applied in in a number of application domains.
- understand different Machine Learning problems deeply enough to select and apply suitable methods and computer tools to solve them,
• formulate and approach new Machine Learning problem settings in a scientific manner; in a creative, critical and systematic way.

Skills and abilities

A Master of Science in Machine Learning will be able to:

• work out solution strategies to different Machine Learning problems, knowing the capabilities and limitations of different methods and tools,
• work efficiently in a teamwork environment in groups with people from different scientific and engineering background,
• communicate with scientists and people active in engineering development in a competent manner both orally and in writing,
• follow and participate in research and development related to the chosen track.

Ability to make judgements and adopt a standpoint

A Master of Science in Machine Learning will be able to:

• critically judge a problem and in an independent manner acquire the information and knowledge that is necessary to establish a qualified opinion,
• formulate and approach new Machine Learning problem settings in a scientific manner; in a creative, critical and systematic way,
• identify the need for further knowledge in the field and take responsibility for keeping her/his personal knowledge up to date.

In addition to this the similar objectives for master degree defined in the Higher Education Ordinance (Högskoleförordningen) are applicable.

Extent and content of the programme

Machine Learning is a two-year (120 ECTS credits) master programme on the advanced level (second cycle). The instruction language is English. Some elective courses are given in Swedish.

The programme consists of a basic curriculum followed by a track. Currently students can choose between the following two tracks: (i) Applied Machine Learning, and (ii) Computational Biology. The courses in the basic curriculum of each track are compulsory and constitute a little more than half of the course work.

Eligibility and selection

General admission requirements: See the KTH general admission requirements for Master’s programmes, link below

Specific admission requirements: The prerequisites for the Master's programme in Machine Learning is a Swedish or foreign degree equivalent to Bachelor’s degree of 180 ECTS credits, with a level in Mathematics and Computer Science equal, or higher, than that of the following courses at KTH: SF1604
Linear algebra (or SF1624), SF1625 Calculus in one variable, SF1626 Calculus in several variables, SF1901 Probability theory and statistics, and DD1341 Introduction to computer science (or DD1320, DD1321, DD1340, DD1344). Applicants must also provide a proof of good knowledge in English.

Selection: If the number of applicants exceeds the number of places there will be a selection from the following criterias:

1. evaluation of university
2. grades from previous study
3. motivation to study
4. merit rating
5. references
6. proficiency in English

Further information

Complete information on the eligibility requirements can be found in the local admission policy of KTH, see

http://intra.kth.se/regelverk/utbildning-forskning/grundutbildning/antagning/1.276218

and on the KTH Studies web pages: http://www.kth.se/en/studies/programmes/master/admission

Implementation of the education

Structure of the education

This programme syllabus, decided by the CSC dean 2013-09-27 is valid for students starting the programme during the study year 2014/2015. Which courses that belong a study year is decided in the fall the year before. Please see ”Study year 1” etc. or the appendices. Changes may occur in the contents of the programme and in the KTH regulations, please see www.kth.se/student.

The KTH academic year is 40 weeks, divided into four periods.

For details about the structure of the academic year see http://www.kth.se/en/student/schema/

The first year in the programme is mainly dedicated to the compulsory courses in the basic curriculum as well as those of each track. The second year mainly consists of elective track courses, freely selected courses, and the degree project.

Courses

The programme is course-based. Lists of courses are included in appendix 1.
Courses

The course goals, prerequisites, contents and examination requirements are found in the course syllabus in the Course and programme directory on the KTH student web. For each study year there is a course list.

For elective courses, the following restrictions apply:

- The number of credits that can be chosen per semester can be limited.
- Elective courses may not overlap a course already taken to a considerable extent.
- Courses on lower levels within a subject than the programme courses may not count as elective courses.

The basic curriculum common to both tracks corresponds to around 25 ECTS credits. In each track, there is an additional set of compulsory courses of around 25 ECTS credits.

A student in the Machine learning track is required to take at least 3 courses, listed in A.2.1, which apply machine learning to particular application domains. He must also take at least 3 courses from those listed in A.2.2 and A.2.3. These latter set of courses focus on theory and software engineering. The remaining credits are obtained from freely elected courses. These courses may be chosen from among the profile courses of the track, other second cycle courses at KTH, and language courses at KTH. First cycle courses at KTH can also be chosen, upon permission from the Programme Director.

Courses are examined in many ways, for example by home assignments that are presented either using oral presentations or written reports, computer assignments, project work or traditional written exams.

After each course a student evaluation is performed and then analysed by the course leader in the course analysis document, which is normally published on the web, see the KTH regulations of course analyses: http://intra.kth.se/regelverk/utbildning-forskning/grundutbildning/kursanalys

Grading system

Courses in the first and the second cycle are graded on a scale from A to F. A-E are passing grades, A is the highest grade. The grades pass (P) and fail (F) are used for courses under certain circumstances.

Since the grading systems differ very much between different countries, the grades are not translated from exchange studies abroad.

Conditions for participation in the programme

Semester enrollment

At the start of each semester the student is required to make a study enrollment for the next semester at My pages.

The study enrollment is required for taking new courses and for study results to be registered.

Approved leave from studies
Approved leave from studies means that the student does not participate in the education during at least one study period. The student has the right to return to the education at a time agreed upon, and has the right to participate in the examination of non-finished courses.

Application for an approved leave is done on according to instructions from the CSC programme office. When the student decides to return to the education, he/she is required to re-enroll to the studies.

Approved leave from studies is not granted during study year 1. Exceptions may be made if there are extraordinary reasons.


Selection of Track

Track selection is made during the first year according to instructions from the CSC school. There are no limitations in terms of the number of students to each track.

Selection of courses

The student is required to apply for admission to all courses he/she wishes to take during the next semester. The student is responsible for having the recommended prerequisites. The application for admission to a course is done according to instructions from the CSC school no later than

- May 15th for the fall semester
- November 15th for the spring semester

Applications made after this date are only granted if there are vacancies in the courses. Applications to language courses with prerequisites should be preceded by a qualification test.

In a few courses, the number of participants is limited. Selection is done by the school responsible for the course.

A student may only take courses that are included in the study plan.

Course registration

The student must, at course start, register for each course. Course registration for compulsory as well as elective courses must be done individually. If the student registers for a course and then decides to not continue, the student must report this as soon as possible.

Registration to a course requires formal acceptance to the course (by the school responsible for the course). Applications should be done according to instructions from the CSC school.

Promotion to second year

At least 45 ECTS credits have to be completed during the first academic year in order for the student to be promoted to the second year of the programme.
Students who do not fulfill these requirements must – in cooperation with the CSC programme office – make an individual study plan for continued studies.

Please see the KTH regulations: http://intra.kth.se/en/regelverk/utbildning-forskning/grundutbildning/1.27217

**Recognition of previous academic studies**

Credits for studies at another university can be transferred. An application form can be found on the KTH Student pages.

The application form is submitted to the CSC Programme Office.

For in-depth information about the KTH policy for credit transfer, see http://intra.kth.se/en/regelverk/utbildning-forskning/grundutbildning/prestationer/1.27200

**Studies abroad**

Students of the programme have the possibility to spend one or two semesters of study at a foreign university, or do their degree project abroad.

For more information, contact the person responsible for International Relations at CSC.

More information can also be found at http://intra.kth.se/regelverk/utbildning-forskning/grundutbildning/utbytesstudier

**Degree project**

Students admitted to the programme are required to perform an individual study in the form of a degree project corresponding to 30 ECTS credits. At least 60 ECTS credits must be completed before the start of the degree project. Of these, 40 ECTS credits must come from the (common and track-specific) compulsory courses.

It is the responsibility of the student to find a suitable project task.

More information about the rules for degree projects at KTH can be found at http://intra.kth.se/en/regelverk/utbildning-forskning/grundutbildning/examensarbete/1.27212

For students on a Master of science of engineering programme not only the requirements set by the selected Master programme to begin the degree project apply but also the requirements from the Master of science of engineering programme.

**Degree**

After completing the programme, the student may apply for the Degree of Master of Science, in Swedish: teknologie masterexamen.

Information on the application process can be found on the KTH Student pages.
Requirements for the Degree of Master of Science

The Degree of Master of Science is obtained after completion of the Machine Learning programme. The programme is designed so that students, when they graduate, have fulfilled national requirements for a degree. This means that the students have completed courses comprising 120 ECTS credits, of which at least 90 ECTS credits are second cycle, and at least 60 ECTS credits (including a 30 ECTS credits degree project) constitute indepth studies in the main field of study.

See also the KTH regulations at http://intra.kth.se/en/regelverk/utbildning-forskning/grundutbildning/examina/1.27227

Appendix 1 - Course list
Appendix 2 - Programme syllabus descriptions
Appendix 1: Course list

Master's Programme, Machine Learning, 120 credits (TMAIM), Programme syllabus for studies starting in autumn 2014

General courses

Year 1

Mandatory courses (27.0 Credits)

<table>
<thead>
<tr>
<th>Course code</th>
<th>Course name</th>
<th>Credits</th>
<th>Edu. level</th>
</tr>
</thead>
<tbody>
<tr>
<td>DA2205</td>
<td>Introduction to the Philosophy of Science and Research Methodology</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td>DD2380</td>
<td>Artificial Intelligence</td>
<td>6.0 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td>DD2431</td>
<td>Machine Learning</td>
<td>6.0 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td>DD2434</td>
<td>Machine Learning, Advanced Course</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
</tbody>
</table>

Supplementary information

Specialization streams are:

- Applied Machine Learning,
- Computational Biology.

Year 2

Mandatory courses (67.5 Credits)

<table>
<thead>
<tr>
<th>Course code</th>
<th>Course name</th>
<th>Credits</th>
<th>Edu. level</th>
</tr>
</thead>
<tbody>
<tr>
<td>DA2205</td>
<td>Introduction to the Philosophy of Science and Research Methodology</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td>DA224X</td>
<td>Degree Project in Computer Science and Communication, Second Cycle</td>
<td>30.0 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td></td>
<td>External admitted master student at CSC</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Track, Computational Biology (MAIC)

Year 1

Mandatory courses (43.5 Credits)

<table>
<thead>
<tr>
<th>Course code</th>
<th>Course name</th>
<th>Credits</th>
<th>Edu. level</th>
</tr>
</thead>
<tbody>
<tr>
<td>DD2398</td>
<td>Quantitative Systems Biology</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td></td>
<td>In A.3.3. as a conditionally elective course.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DD2399</td>
<td>Omic Data and Systems Biology</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td></td>
<td>In A.3.3. as a conditionally elective course.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DD2402</td>
<td>Advanced Individual Course in Computational Biology</td>
<td>6.0 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td></td>
<td>In A.3.3. as a conditionally elective course.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DD2404</td>
<td>Applied Bioinformatics</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td>DD2435</td>
<td>Mathematical Modelling of Biological Systems</td>
<td>9.0 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td>SK2530</td>
<td>Introduction to Biomedicine</td>
<td>6.0 hp</td>
<td>Second cycle</td>
</tr>
</tbody>
</table>

Conditionally elective courses

<table>
<thead>
<tr>
<th>Course code</th>
<th>Course name</th>
<th>Credits</th>
<th>Edu. level</th>
</tr>
</thead>
<tbody>
<tr>
<td>DD2400</td>
<td>Cellular and Molecular Biology</td>
<td>15.0 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td>DD2401</td>
<td>Neuroscience</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td>DD2427</td>
<td>Image Based Recognition and Classification</td>
<td>6.0 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td>DD2432</td>
<td>Artificial Neural Networks and Other Learning Systems</td>
<td>6.0 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td>DD2447</td>
<td>Statistical Methods in Applied Computer Science</td>
<td>6.0 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td></td>
<td>Could be taken year 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DD2476</td>
<td>Search Engines and Information Retrieval Systems</td>
<td>9.0 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td>SF1811</td>
<td>Optimization</td>
<td>6.0 hp</td>
<td>First cycle</td>
</tr>
<tr>
<td>SF2950</td>
<td>Applied Mathematical Statistics</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
</tbody>
</table>

Supplementary information

A.3.1 Compulsory courses in alternative 1 include: DD2402, DD2404 and DD2399.

A.3.2. Compulsory courses in alternative 2 include: SK2530, DD2435 and DD2398.

A.3.3. Conditionally elective courses within the specialization, at least 3 of them must be taken.
Year 2

Mandatory courses (6.0 Credits)

<table>
<thead>
<tr>
<th>Course code</th>
<th>Course name</th>
<th>Credits</th>
<th>Edu. level</th>
</tr>
</thead>
<tbody>
<tr>
<td>SK2530</td>
<td>Introduction to Biomedicine</td>
<td>6.0 hp</td>
<td>Second cycle</td>
</tr>
</tbody>
</table>

Conditionally elective courses

<table>
<thead>
<tr>
<th>Course code</th>
<th>Course name</th>
<th>Credits</th>
<th>Edu. level</th>
</tr>
</thead>
<tbody>
<tr>
<td>BB2440</td>
<td>Bioinformatics and Biostatistics</td>
<td>7.0 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td>DD2404</td>
<td>Applied Bioinformatics</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td>DD2429</td>
<td>Computational Photography</td>
<td>6.0 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td>DD2435</td>
<td>Mathematical Modelling of Biological Systems</td>
<td>9.0 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td>DD2447</td>
<td>Statistical Methods in Applied Computer Science</td>
<td>6.0 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td>SF2940</td>
<td>Probability Theory</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
</tbody>
</table>

Supplementary information

A.3.2 Compulsory Courses, Alternative 2:
- SK2530 Introduction to Biomedicine 6 hp.

A.3.3 Conditionally Elective Courses (NOTE! At least three courses must be read!):
- SK2530 Introduction to Biomedicine 6 hp,
- DD2429 Computational Photography 6 hp,
- BB2440 Bioinformatics and Biostatistics, 7 hp,
- SF2940 Probability Theory, 7,5, hp,
- DD2435 Mathematical Modelling of Biological Systems, 9 hp,
- DD2447 Statistical Methods in Applied Computer Science, 6 hp,
- DD2404 Applied Bioinformatics, 7,5 hp.

Track, Applied Machine Learning (MAID)

Year 1

Conditionally elective courses

<table>
<thead>
<tr>
<th>Course code</th>
<th>Course name</th>
<th>Credits</th>
<th>Edu. level</th>
</tr>
</thead>
<tbody>
<tr>
<td>DD1368</td>
<td>Database Technology</td>
<td>6.0 hp</td>
<td>First cycle</td>
</tr>
<tr>
<td>DD2257</td>
<td>Visualization</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td>DD2352</td>
<td>Algorithms and Complexity</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
</tbody>
</table>
DD2395  **Computer Security**  
Can be taken in year 2.  
6.0 hp  Second cycle

DD2401  **Neuroscience**  
7.5 hp  Second cycle

DD2402  **Advanced Individual Course in Computational Biology**  
6.0 hp  Second cycle

DD2423  **Image Analysis and Computer Vision**  
7.5 hp  Second cycle

DD2427  **Image Based Recognition and Classification**  
6.0 hp  Second cycle

DD2432  **Artificial Neural Networks and Other Learning Systems**  
6.0 hp  Second cycle

DD2438  **Artificial Intelligence and Multi Agent Systems**  
15.0 hp  Second cycle

DD2447  **Statistical Methods in Applied Computer Science**  
Can be taken in year 2.  
6.0 hp  Second cycle

DD2471  **Modern Database Systems and Their Applications**  
7.5 hp  Second cycle

DD2476  **Search Engines and Information Retrieval Systems**  
9.0 hp  Second cycle

DT2112  **Speech Technology**  
7.5 hp  Second cycle

DT2118  **Speech and Speaker Recognition**  
7.5 hp  Second cycle

EL2320  **Applied Estimation**  
7.5 hp  Second cycle

EN2202  **Pattern Recognition**  
Can be taken in year 2.  
7.5 hp  Second cycle

SF1811  **Optimization**  
6.0 hp  First cycle

SF2568  **Parallel Computations for Large- Scale Problems**  
7.5 hp  Second cycle

SF2950  **Applied Mathematical Statistics**  
7.5 hp  Second cycle

**Supplementary information**

**A.2.1 Conditionally Elective Courses - Application Domains.**

*Note!* At least **four (4)** of them must be taken from A.2.1 and at least **two (2)** of the courses from A.2.2. and A.2.3:

- Included in Computer Vision: DD2423 and DD2427.

- Included in Speech: DT2112 and DT2118.

- Included in Visualization: DD2257.

- Included in Robotics: DD2438.

- Included in Databases/Information Retrieval: DD1368, DD2476 and DD2471.

- Included in Computational Biology: DD2402 and DD2401.

**A.2.2. Conditionally elective courses - Theory:**

- Included in Mathematics: EL2320 and SF1811.

- Included in Statistics and Probability: DD2447, SF2950 and SF2945.
- Included in Machine Learning: EN2202 and DD2432.

A.2.3. Conditionally elective courses - Computer Science:

- Included in Parallel Computing: SF2568.

- Included in Theory: DD2352.

- Included in Security: DD2395.

Year 2

Conditionally elective courses

<table>
<thead>
<tr>
<th>Course code</th>
<th>Course name</th>
<th>Credits Edu. level</th>
</tr>
</thead>
<tbody>
<tr>
<td>DD2387</td>
<td>Program System Construction Using C++</td>
<td>6.0 hp Second cycle</td>
</tr>
<tr>
<td>DD2395</td>
<td>Computer Security</td>
<td>6.0 hp Second cycle</td>
</tr>
<tr>
<td>DD2404</td>
<td>Applied Bioinformatics</td>
<td>7.5 hp Second cycle</td>
</tr>
<tr>
<td>DD2418</td>
<td>Language Engineering</td>
<td>6.0 hp Second cycle</td>
</tr>
<tr>
<td>DD2423</td>
<td>Image Analysis and Computer Vision</td>
<td>7.5 hp Second cycle</td>
</tr>
<tr>
<td>DD2425</td>
<td>Robotics and Autonomous Systems</td>
<td>9.0 hp Second cycle</td>
</tr>
<tr>
<td>DD2429</td>
<td>Computational Photography</td>
<td>6.0 hp Second cycle</td>
</tr>
<tr>
<td>DD2435</td>
<td>Mathematical Modelling of Biological Systems</td>
<td>9.0 hp Second cycle</td>
</tr>
<tr>
<td>DD2447</td>
<td>Statistical Methods in Applied Computer Science</td>
<td>6.0 hp Second cycle</td>
</tr>
<tr>
<td>EL2320</td>
<td>Applied Estimation</td>
<td>7.5 hp Second cycle</td>
</tr>
<tr>
<td>EQ2340</td>
<td>Pattern Recognition</td>
<td>7.5 hp Second cycle</td>
</tr>
<tr>
<td>SF2940</td>
<td>Probability Theory</td>
<td>7.5 hp Second cycle</td>
</tr>
</tbody>
</table>

Supplementary information

NOTE!
At least four courses from A.2.1 and two from A.2.2 and two from A.2.3 shall be taken during study year 1-2.

A.2.1 Conditionally Elective Courses - Application Domains

COMPUTER VISION:
DD2429 Computational Photography, 6 hp,
DD2423 Image Analysis and Computer Vision, 7.5.

NATURAL LANGUAGE PROCESSING:
DD2418 Language Engineering 6.
ROBOTICS:

COMPUTATIONAL BIOLOGY:
DD2404 Applied Bioinformatics 7,5
DD2435 Neuronnéts- och biomodellering 9.

A.2.2 Conditionally Elective Courses - Theory

MATHEMATICS:
EL2320 Applied Estimation 7,5.

STATISTICS & PROBABILITY:
SF2940 Probability Theory 7,5.

MACHINE LEARNING:
EQ2340 Pattern Recognition 7,5.

A.2.3 Conditionally Elective Courses - Computer Science

SOFTWARE ENGINEERING:
DD2387 Program System Construction Using C++, 6 hp.

SECURITY:
DD2395 Computer Security, 6 hp.
Appendix 2: Specialisations

Master's Programme, Machine Learning, 120 credits (TMAIM), Programme syllabus for studies starting in autumn 2014

Track, Computational Biology (MAIC)

Track, Applied Machine Learning (MAID)