FACULTY OF SCIENCE

Complex Adaptive Systems, Master's Programme, 120 credits

Complex Adaptive Systems, Master Program, 120 högskolepoäng

Programme code: N2CAS

Second cycle / Avancerad nivå

1. Confirmation

This programme syllabus was confirmed by the Faculty of Science on 17-10-2006 (G) and was last revised on 10-10-2022 (GU 2022/2772) by the Dean of the Faculty to be valid from 10-10-2022, Autumn semester 2023.

Responsible Department/equivalent: Department of Physics

2. Purpose

Today we are forced to understand the dynamics of increasingly complex phenomena where standard simulation methods are inadequate. An example are fluctuations of share and option prices determining the stability of our economy. Other examples are the dynamics of dust particles in the exhaust of diesel engines, the dynamics of biological or artificial populations, or even the climate.

At the same time artificial intelligence and machine learning, using for example artificial neural networks, are also topics that can be described as complex systems.

The aim of the programme is twofold: first to demonstrate and teach how to understand and model the behaviour of complex systems (occuring for instance in the context of evolution, chaos, and societal systems), and second to gain an understanding of and hands-on practice in using adaptive systems and machine learning.

The computer modeling and analytical skills acquired in the programme open a wide range of possibilities on the employment market. The interdisciplinary nature of the programme in particular has proven to be an asset on the job market. As far as industry is concerned, our students have found employment in software development and consulting, in research and development, management, in the financial sector. Many jobs are related to machine learning and autonomous systems. Quite a few students also continue towards a PhD in a wide spectrum of academic fields.

3. Entry requirements

A Bachelor's degree or the equivalence to 180 Swedish credit points (p) or 180 ECTS credits at an accredited university. The programme is open to international and domestic students with a degree in the Natural, Engineering, or Mathematical Sciences. At least 30 credits of mathematics (including linear algebra and analysis) and programming. Applicants must prove their knowledge of English: English 6/English B from Swedish Upper Secondary School or the equivalent level of an internationally recognized test, for example TOEFL, IELTS.

4. Higher education qualification and main field of study

This programme leads to a Degree of Master of Science (120 credits) with a major in Physics with Specialization in Complex Adaptive Systems (Naturvetenskaplig masterexamen med huvudområdet Fysik med inriktning mot komplexa adaptiva system).

5. Outcomes

General outcomes for Degree of Master (120 credits)

Knowledge and understanding

For a Degree of Master (120 credits) the student shall

- demonstrate knowledge and understanding in the main field of study, including both broad knowledge of the field and a considerable degree of specialised knowledge in certain areas of the field as well as insight into current research and development work, and
- demonstrate specialised methodological knowledge in the main field of study.

Competence and skills

For a Degree of Master (120 credits) the student shall

- demonstrate the ability to critically and systematically integrate knowledge and analyse, assess and deal with complex phenomena, issues and situations even with limited information
- demonstrate the ability to identify and formulate issues critically, autonomously and creatively as well as to plan and, using appropriate methods, undertake advanced tasks within predetermined time frames and so contribute to the formation of knowledge as well as the ability to evaluate this work
- demonstrate the ability in speech and writing both nationally and internationally to clearly report and discuss his or her conclusions and the knowledge and arguments on which they are based in dialogue with different audiences, and
- demonstrate the skills required for participation in research and development work or autonomous employment in some other qualified capacity.

Judgement and approach

For a Degree of Master (120 credits) the student shall

- demonstrate the ability to make assessments in the main field of study informed by relevant disciplinary, social and ethical issues and also to demonstrate awareness of ethical aspects

of research and development work
- demonstrate insight into the possibilities and limitations of research, its role in society and the responsibility of the individual for how it is used, and
- demonstrate the ability to identify the personal need for further knowledge and take responsibility for his or her ongoing learning.

Local outcomes

The programme aims at:
1. providing general knowledge of the signi?cance of, the problems posed by, and the methods employed to understanding complex systems observed in the Natural and Engineering Sciences. The knowledge builds on that associated typically with the Bachelor's level, but it goes beyond that in that it should enable the students to develop/apply their own ideas, often in a research context.
2. enabling students to specialise in one of the following three areas in Complex Systems: Adaptive Systems (Robotics & Control), Information and Evolution, and Physics of Complex Systems. These areas are closely connected to research performed at Göteborg and Chalmers Universities.
3. providing the students with the necessary analytical, programming and modeling skills to work successfully under supervision in one of the above areas, or to apply their problem-solving skills in a suitable industry project in collaboration with their academic teachers, and last but not least to use their skills effectively in new or initially unfamiliar, interdisciplinary environments.
4. providing the students with criteria and methods to critically re?ect their results and put them into context.
5. enabling students to communicate their results, to describe the hypotheses and assumptions these rest on to specialist and to non-specialst audiences.
6. enabling the students to continue to study or work independently, autonomously, and self directed if necessary, but enabling them to also successfully work within an interdisciplinary research team.

6. Content and structure

The programme provides an interdisciplinary and international learning environment. It is taught in collaboration with several departments at Chalmers University.

The basic format of the teaching is problem solving in the form of projects and hand-in problems that are solved using mathematical programming, primarily with Matlab. The aim is to give the students solid programming skills and training on how to use modern algorithms and to model complex systems. Lectures give an introduction and background to the material, which is then applied in the student projects. Typically the examination also includes a written exam to test more basic aspects not examined by the projects and as a quality assurance on the individual examination.

The following set of courses makes up the standard curriculum. They are not mandatory but highly recommended. (All courses 7,5 ECTS)

- FIM711 Stochastic Optimization

- FIM720 Artificial Neural Networks
- FIM730 Complex Systems Seminar (1 year course)
- FIM770 Dynamical systems
- FIM750 Simulation of Complex Systems
- FIM740 Computational Biology A

The following set of courses are recommended electives. The students can also take other elective courses, in physics, mathematics, natural sciences, or computer science. (Depending on individual eligibility.)

- FIM762 Intelligent agents
- FIM780 Information Theory for Complex Systems
- FIM764 Autonomous robots
- FYM360 Advanced machine learning with neural networks
- FIM786 Nonequilibrium Processes in Physics Chemistry and Biology
- FIM800 Humanoid Robotics
- FIM784 Game theory and rationality

7. Other information

The study programme will be followed up and evaluated in accordance with the applicable *Policy för kvalitetssäkring och kvalitetsutveckling av utbildning vid Göteborgs universitet* (Policy for the Quality assurance and Quality Development of Education at the University of Gothenburg).