Systems, Cybernetics and Complexity, 7.5 credits

System, cybernetik och komplexitet, 7,5 högskolepoäng

Course code:	FOID007
Third-cycle subject:	Computer Science
School:	IDT
Valid from:	VT25
Established by:	Dean of School
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Last modified:	-
Level of education:	Third cycle level

Course objective

This course covers the interrelated topics of systems theory, cybernetics, and complexity theory. A *system* is a group of elements that interact in a way that creates behavior or properties that do not exist in the individual elements. An important question is how to design systems to fulfil certain purposes. This often involves combining elements of different kinds, such as technology, humans, organizations, or natural objects. It also involves controlling their interactions, which is studied in the field of *cybernetics*. This is a challenge, since many systems are of immense *complexity*, due to a large variety of elements and numerous interrelations. Seemingly simple elements, arranged in straightforward ways, can still exhibit surprising behavior that should be avoided if it could be predicted.

The system notion dates back to antiquity but is increasingly important in today's society, where more and more technical solutions and people are interrelated. Contemporary examples include the dynamics of social media networks, the mechanisms of climate change, how the central banks try to control inflation through interest rates, and the effects on society of pandemic policies. The same principles also apply at a smaller scale in the development of new products, or in the organization of a company.

The objective of this interdisciplinary course is to provide the students with a firm understanding of the system concept, and what different variants exist. The course gives an exposé of the historical development of the field and puts those

results in a contemporary context. Different flavors of systems theory and cybernetics are explained. Large and complex systems, especially socio-technical ones, are emphasized, and the nature of complexity is investigated.

With this knowledge at hand, the students will be equipped with a broader and deeper understanding of the topic. This enables progressive action in complex situations in different domains, such as sustainability, where collaboration among different actors is a prerequisite.

Course content

The content of the course is divided into five modules:

1. *Systems theory*. Definitions of the system concept, different kinds of systems, observers, emergence, holism vs. reductionism.
2. *Cybernetics*. Models, adaptive control, feedback and feedforward loops, requisite variety, homeostasis, autopoesis.
3. *Hard systems and dynamic models*. Systems engineering, dynamic modeling, and simulation.
4. *Sociotechnical systems*. Systems thinking, the soft systems method, viable systems, second-order cybernetics, wicked problems.
5. *Complexity*. Definitions of complexity, complex adaptive systems, non-linear systems and chaos theory, entropy, complexity measures.

The focus of the course is to provide an overview of concepts and their relations, that apply to a broad set of sociotechnical applications. This is in contrast with other courses, such as in control theory, that put more emphasis on the mathematical theory behind a limited set of concepts for use mainly in engineered systems.

Intended learning outcomes

After completing the course, the students will be able to:

1. Explain key concepts in systems theory and cybernetics.
2. Summarize and compare different schools of thought in the systems field.
3. Compare different notions of complexity.
4. Apply systems thinking methods to contemporary problems within their field of study.
5. Analyze and evaluate systemic situations.

The intended qualitative targets in relation to the Higher Education Ordinance, appendix 2.

Knowledge and understanding

For the Degree of Doctor, the doctoral student shall demonstrate:

- A1: broad knowledge and systematic understanding of the research field as well as advanced and up-to-date specialised knowledge in a limited area of this field, and
- A2: familiarity with research methodology in general and the methods of the specific field of research in particular.

Specifically, the course provides a systems-theoretic framework that is a relevant partial foundation for many research fields (A1) and introduces methods related to systems-oriented research (A2).

Competence and skills

For the Degree of Doctor, the doctoral student shall demonstrate:

- B1: the capacity for scholarly analysis and synthesis as well as to review and assess new and complex phenomena, issues, and situations autonomously and critically,
- B2: the ability to identify and formulate issues with scholarly precision critically, autonomously, and creatively, and to plan and use appropriate methods to undertake research and other qualified tasks within predetermined time frames and to review and evaluate such work,

Specifically, the course provides insights into complexity (B1) and lets the student practice writing scholarly texts in the systems field (B2).

Judgement and approach

For a Degree of Doctor, the doctoral student shall demonstrate

- C2: specialised insight into the possibilities and limitations of research, its role in society, and the responsibility of the individual for how it is used.

Specifically, the course discusses holistic approaches that complement the traditional reductionist methods of science and shows their relevance to societal problems (C2).

Teaching formats

The course consists of one teaching session on campus per course module. Each session consists of two half-days with lectures where the teacher presents the theoretical content and seminars and exercises where the students apply the theory and develop skills under the teacher's guidance. In addition, there is a final session where the students present and discuss their individual written reports.

In between sessions, students work individually by reading literature to develop a deeper understanding of theoretical concepts and preparing for coming sessions and the written report.

Examination

OBN1	Participate actively in lectures, seminars, and exercises with adequate preparation; addresses primarily learning outcomes 1-3 (3 hp)
INL1	Write a report; addresses primarily learning outcome 4 (3 hp)
SEM1	Present the written report and act as discussant of another student's report; addresses primarily learning outcome 5 (1.5 hp)

Grade

Examinations included in the course are assessed according to a two-grade scale, fail or pass.

Grades are to be decided by a teacher specially appointed by the university.

A person who has not passed the regular examination shall be given the opportunity to retake the test.

Requirements

To participate in the course and the examinations included in the course, the applicant must be admitted to doctoral studies at Mälardalen University.

The course is suitable for any student holding an MSc in computer science, any field of engineering, or similar areas.

Selection criteria

Doctoral students admitted to other subjects at Mälardalen University may be admitted to the course, subject to availability. The same applies to doctoral students admitted to other higher education institutions. Selection of applicants will be made in accordance with the ranking below.

1. Doctoral students in computer science and in electronics
2. Doctoral students at Mälardalen University
3. Doctoral students at other universities