All course data

FRTN75
Inlärningsbaserad reglering
Learning-Based Control

Credits: 7.5
Grading scale: TH (U,3,4,5)
Course type: Programme course
Cycle (proposal by the department): A
Cycle (decision by the education board): A

Language of instruction: The course will be given in English
The course is suitable for the incoming exchange students: Yes

Admission restrictions: Number of students is limited to 60
The course can be called off:
The course has special application (not in the students' portal): No

Persons linked to the course

Role	Name	Email	Lucat ID
Course coordinator	Anders Rantzer	anders.rantzer@control.lth.se	cont-ara
Director of studies	Anton Cervin	anton.cervin@control.lth.se	cont-ace
Teacher	Bo Bernhardsson	bo.bernhardsson@control.lth.se	cont-bbe

Main field of study and advancement within main field

Main field of study	Advancement in the main field
	AXX - Second cycle, in-depth level of the course cannot be classified

Education area

Utb-område	Value
Tekniska området	100

Course information - Swedish

Course web page www.control.lth.se/course/FRTN75

Additional information
Ersätter FRTN15 Prediktiv reglering.

Course information - English

Course web page www.control.lth.se/course/FRTN75

Additional information
Replaces FRTN15 Predictive Control.

Course plan - Swedish

Assumed prior knowledge
FRTF05 Reglerteknik AK.

Admission selection

Avklarade högskolepoäng inom programmet. Förtur ges till studenter vars program har kursen listad i läro- och timplanen.

Assessment
Skriftlig examen (5 tim), tre laborationer. Vid färre än fem anmälda kan omtentamina ges på muntlig form.

Aim

Kursen förklarar grundläggande teori och metodik att ta fram reglertekniska styrlagar baserat på uppmätta in- och utsignaldata. Kursens mål är att studenterna ska lära sig viktiga principer och metoder inom området inlärningsbaserad reglering, samt förstå deras begränsningar.

Learning outcome - Knowledge and understanding
For a passing grade the student must

- kunna förstå algoritmer för flervariabel systemidentifiering, inklusive uppskattningar av modellfel
- förstå betydelsen av excitation
- förstå grundprincipen för dynamisk programmering
- förstå antaganden och approximationer bakom vanliga varianter av förstärkningsinlärning
- beskriva de grundläggande egenskaperna och begränsningarna hos komponenter baserade på maskininlärning, såsom neuronnät och klassificerare.

Learning outcome - Competences and skills
For a passing grade the student must

- kunna implementera flervariabla systemidentifieringsprocedurer och genomföra modellval och avgöra hur en given datamängd ska analyseras
- kunna simulera och använda identifierade modeller i flervariabel reglersyntes
- kunna implementera enkla adaptiva regulatorer
- kunna tillämpa några varianter av förstärkningsinlärning
- kunna implementera banföljningsalgoritmer baserade på dynamisk programmering.

Learning outcome - Judgement and approach
For a passing grade the student must

- förstå den konfidens som är möjlig att uppnå med databaserade reglermetoder
- visa förmåga till lagarbete och samverkan i grupp vid laborationer.

Contents

Att ta fram lämpliga modeller för beskrivning dynamiska system är ett centralt problem i reglertekniken, och ofta avgörande för framtagning av robusta och välpresterande styrlagar. När fysikaliska samband inte är fullt kända genereras modellerna och styrlagarna istället helt eller delvis från uppmätta data, genom systemidentifiering, maskininlärning eller adaptiv reglering. Avsikten med kursen är att förklara grundläggande principer för hur detta går till.

Första delen av kursen viks åt adaptiv reglering och systemidentifiering för system med flera insignaler och utsignaler. Fokus ligger på tillståndsmodeller och metoder för att generera dessa, inklusive gråbox-identifiering. Vi beskriver iterativa metoder för inlärning, liksom modellförenkling i syfte att minska antalet tillstånd.

Den andra delen av kursen viks åt förstärkningsinlärning (reinforcement learning). Här ingår teorin för dynamisk programmering och olika approximativa metoder för detta. Policyiteration behandlas, liksom diskret och kontinuerlig banplanering.

En tredje del av kursen behandlar reglertekniskt utnyttjande av färdiga komponenter, exempelvis sensorer, som tagits fram genom maskininlärning.

Laborationer: 1: Multivariabel systemidentifiering på nätverk. 2: Banplanering och förstärkningsbaserad inlärning. 3: Bildbehandling i sluten loop.

Course plan - English

Assumed prior knowledge
FRTF05 Automatic Control, Basic Course.

Admission selection
Completed university credits within the programme. Priority is given to students enrolled on programmes that include the course in their

curriculum.

Assessment
Written exam (5 hours), three laboratory exercises. In the case of less than 5 registered students, the retake exams may be given in oral form.

Aim

The course provides fundamental theory and methodology for developing control laws based on measured input and output signal data. The aim of the course is that the students should learn the important principles within the area of learning-based control, and to understand their limitations.

Learning outcome - Knowledge and understanding
For a passing grade the student must

- be able to understand algorithms for multivariable system identification, including estimations of model errors
- understand the importance of excitation
- uinderstand the basic principle of dynamic programming
- understand the assumptions and approximations behind common variants of reinforcement learning
- understand the fundamental properties and limitations of components based on machine learning, such as neural networks and classifiers.

Learning outcome - Competences and skills
For a passing grade the student must

- be able to implement multivariable system identification procedures and perform model choices and determine how to analyse a given dataset
- be able to simulate and use identified models in a multivariable control synthesis
- be able to implement simple adaptive controllers
- be able to apply some variants of reinforcement learning
- be able to implement path-following algorithms based on dynamic programming.

Learning outcome - Judgement and approach
For a passing grade the student must

- understand the achievable confidence when using data-driven control methods
- show ability for teamwork and group collaboration during laboratory experiments.

Contents

The development of suitable models for describing dynamical systems is a central problem within automatic control, and it is critical for the development of robust and high performance control laws. When relationships between physical quantities are not fully known, then models and the control laws may instead be generated by measurement data, through system identification, machine learning, or adaptive control. The purpose of the course is to teach the basic principles of how this is done.

The first part of the course is devoted to adaptive control and system identification for systems with several input and output signals. The focus is on state-space models and methods for generating these, including greybox identification. We describe iterative methods for learning, as well as model reduction for the purpose of reducing the dimension of the state space.

The second part of the course is devoted to reinforcement learning. This includes the theory of dynamic programming and various approximate methods thereof. Policy iteration is explained, as well as discrete and continuous path planning.

The third part of the course deals with the usage of complete components for the purpose of control, for instance sensors, that have been developed using machine learning.

Course literature

Fri text

Title	Subtitle	ISBN	Year of publication	Author	Publishing House	Text (Swe)	Text (En)
System Identification: Theory for the user		0136566952	1998	Lennart Ljung	Pearson Education		

Title	Subtitle	ISBN	Year of publication	Author	Publishing House	Text (Swe)	Text (En)
						Föreläsningsbilder, övningsmaterial och laborationsmanualer finns tillgängliga på kurshemsidan.	Lecture slides, exercise material and laboratory manuals are available on the course homepage.

Overlap

Här anges om kursen överlappar andra kurser eller ej. Som standard (för nya kurser) sätts att kursen har överlapp, men inga överlappande kurser är ifyllda. För att kunna lämna in kursen krävs att minst en överlappande kurs är ifylld, eller också att man fyllt i att inga överlappande kurser finns.

Course code	Credits
FRTN15	4.0

Parts of the course

The parts of the course

Course part code	Course part name (Swe)	Course part name (En)	Credits	Grading scale	Schedule in ordinary examination period	Schedule in reexamination period
0121	**Tentamen**	**Examination**	4.5	TH (U,3,4,5)	✔	✔
Assessment (Swe)	Godkänd tentamen					
Assessment (En)	Passed exam					
The course part includes (Swe)						
The course part includes (En)						
Other information (Swe)						
Other information (En)						
0221	**Laboration 1**	**Laboratory Work 1**	1.0	UG (U,G)		
Assessment (Swe)	Godkända förberedelseuppgifter och godkänt genomförande av laborationen					
Assessment (En)	Preparation exercises and approved participation in the laboratory					
The course part includes (Swe)						
The course part includes (En)						
Other information (Swe)						
Other information (En)						

Course part code	Course part name (Swe)	Course part name (En)	Credits	Grading scale	Schedule in ordinary examination period	Schedule in reexamination period
0321	**Laboration 2**	**Laboratory Work 2**	1.0	UG (U,G)		
Assessment (Swe)	Godkända förberedelseuppgifter och godkänt genomförande av laborationen					
Assessment (En)	Preparation exercises and approved participation in the laboratory					
The course part includes (Swe)						
The course part includes (En)						
Other information (Swe)						
Other information (En)						
0421	**Laboration 3**	**Laboratory Work 3**	1.0	UG (U,G)		
Assessment (Swe)	Godkända förberedelseuppgifter och godkänt genomförande av laborationen					
Assessment (En)	Preparation exercises and approved participation in the laboratory					
The course part includes (Swe)						
The course part includes (En)						
Other information (Swe)						
Other information (En)						

Programme curricula

Shows which programs and specializations the course is linked to, if the course is mandatory, elective or alternative mandatory and in which year of studies the course is part of and the lowest year it is permitted to admit the course

Programme	Specialization	The course is	Included in year	Permitted from year
BME - Biomedical Engineering				
Footnote (Swe)	Ersätter FRTN15 Prediktiv reglering.			
Footnote (En)	Replaces FRTN15 Predictive Control.			
	General	Elective	4	4
C - Information and Communication Engineering				
Footnote (Swe)	Ersätter FRTN15 Prediktiv reglering.			
Footnote (En)	Replaces FRTN15 Predictive Control.			
	General	Elective	4	4
D - Computer Science and Engineering				

Programme	Specialization	The course is	Included in year	Permitted from year
Footnote (Swe)	Ersätter FRTN15 Prediktiv reglering.			
Footnote (En)	Replaces FRTN15 Predictive Control.			
	Systems, Signals and Control	Elective	4	4
	Machine Intelligence	Elective	4	4
E - Electrical Engineering				
Footnote (Swe)	Ersätter FRTN15 Prediktiv reglering.			
Footnote (En)	Replaces FRTN15 Predictive Control.			
	Control and Automation	Elective	4	4
F - Engineering Physics				
Footnote (Swe)	Ersätter FRTN15 Prediktiv reglering.			
Footnote (En)	Replaces FRTN15 Predictive Control.			
	General	Elective	4	4
	Control Systems	Elective	4	4
	Machine Intelligence	Elective	4	4
MMSR - Master's programme in Machine Learning, Systems and Control				
Footnote (Swe)	Ersätter FRTN15 Prediktiv reglering.			
Footnote (En)	Replaces FRTN15 Predictive Control.			
	General	Elective	1	1
Pi - Engineering Mathematics				
Footnote (Swe)	Ersätter FRTN15 Prediktiv reglering.			
Footnote (En)	Replaces FRTN15 Predictive Control.			
	Systems, Signals and Control	Elective	4	4

Time table

Show timetables for each program, ie the study periods of the course and the number of hours for each type of timetable hours for each study period

Programme	Läsperiod 1					Läsperiod 2					Läsperiod 3					Läsperiod 4				
	F	O	L	H	S	F	O	L	H	S	F	O	L	H	S	F	O	L	H	S
BME - Biomedical Engineering											28	28	12	0	130					
C - Information and Communication Engineering											28	28	12	0	130					
D - Computer Science and Engineering											28	28	12	0	130					
E - Electrical Engineering											28	28	12	0	130					
F - Engineering Physics											28	28	12	0	130					

Programme	Läsperiod 1					Läsperiod 2					Läsperiod 3					Läsperiod 4				
	F	O	L	H	S	F	O	L	H	S	F	O	L	H	S	F	O	L	H	S
MMSR - Master's programme in Machine Learning, Systems and Control											28	28	12	0	130					
Pi - Engineering Mathematics											28	28	12	0	130					

Status of the course

Status on the course set by the department, the programmes or the education board

Department (7161 Automatic Control)

Status set by the department

EduStatus DEP	Submission course offer	Submission course plan	Cost factor	Cycle DEP
Active	Approved by dep/prefect	Approved by dep/prefect	B	A
Motivation	Denna kurs ersätter FRTN15 Prediktiv reglering. Innehållet är moderniserat och lägger mera fokus på datadrivna metoder såsom förstärkningsinlärning och flervariabel processidentifiering. Innehållet är också anpassat för att bättre komplettera de nya kurserna FRTN55 Reglerteknik, fortsättningskurs, och FRTN65 Modellering och inlärning från data.			

Programmes

Status set by the programmes

	Programme	EduStatus PROG	Decision PROG
BME	**Biomedical Engineering**	Active	Decided
Comments			
C	**Information and Communication Engineering**	Active	Decided
Comments			
D	**Computer Science and Engineering**	Active	Decided
Comments			
E	**Electrical Engineering**	Active	Decided
Comments			
F	**Engineering Physics**	Active	Decided
Comments	Ersätter FRTN15.		
MMSR	**Master's programme in Machine Learning, Systems and Control**	Active	Decided
Comments			
Pi	**Engineering Mathematics**	Active	Decided
Comments	Ersätter FRTN15.		

Course education board

Status set by the board of education

	Assigned board	Cost factor BRD	Cycle BRD	Edu-StatusBRD	Decision BRD	Fixing date for course plan	Decision Course plan
	PLED F/Pi	B	A	Active	Decided		Undecided
Comments	Ersätter FRTN15. Kurskod: FRT						