

SDSC8015: MACHINE LEARNING AND CONTROL THEORY

Effective Term

Semester B 2024/25

Part I Course Overview

Course Title

Machine Learning and Control Theory

Subject Code

SDSC - Data Science

Course Number

8015

Academic Unit

Data Science (DS)

College/School

College of Computing (CC)

Course Duration

One Semester

Credit Units

3

Level

R8 - Research Degree

Medium of Instruction

English

Medium of Assessment

English

Prerequisites

Nil

Precursors

Nil

Equivalent Courses

Nil

Exclusive Courses

Nil

Part II Course Details

Abstract

Machine Learning relies on the theory of optimization. However, the most successful part, which is Deep Learning relies on Control Theory. This is a recent discovery for the Machine Learning community, and it is the object of active research. The deep learning structure is based on a sequence of layers of neural nets. With an infinite number of layers, one obtains a structure amenable to Control Theory. The class will provide all the concepts and methods, in optimization and control theory, which are important and currently used in practice and in research. The models are not simply deterministic. So stochastic control will also be presented. In addition, the connection with the topic of identification of dynamical systems will be explained and developed. Reinforcement learning which is another aspect of Machine Learning, is closely linked with MDP, Markov Decision Processes. We also present Bayesian Learning, with an application in inventory control.

Course Intended Learning Outcomes (CILOs)

CILOs		Weighting (if app.)	DEC-A1	DEC-A2	DEC-A3
1	Describe the fundamental knowledge on the mathematical methods of Machine Learning	30	x		
2	Obtain the background necessary for research	30		x	
3	Explain and identify successful methods	15	x		
4	Explain how to deal with Dynamical Systems	15		x	
5	Apply knowledges taught to applications	10			x

A1: Attitude

Develop an attitude of discovery/innovation/creativity, as demonstrated by students possessing a strong sense of curiosity, asking questions actively, challenging assumptions or engaging in inquiry together with teachers.

A2: Ability

Develop the ability/skill needed to discover/innovate/create, as demonstrated by students possessing critical thinking skills to assess ideas, acquiring research skills, synthesizing knowledge across disciplines or applying academic knowledge to real-life problems.

A3: Accomplishments

Demonstrate accomplishment of discovery/innovation/creativity through producing /constructing creative works/new artefacts, effective solutions to real-life problems or new processes.

Learning and Teaching Activities (LTAs)

LTAs		Brief Description	CILO No.	Hours/week (if applicable)
1	Lectures	Students will engage in formal presentation of concepts and methods.	1, 2, 3, 4	
2	Readings	Students will study the relevant articles and research papers.	1, 2, 3, 4, 5	
3	Home Assignments	Students will work on exercises and homework problems to get facilitate and understand the course material.	1, 2, 3, 4	

Assessment Tasks / Activities (ATs)

ATs		CILO No.	Weighting (%)	Remarks (e.g. Parameter for GenAI use)
1	Participation	1, 2, 3, 4	15	
2	Home Assignments : Exercises	1, 2, 3, 4	35	
3	Projects in groups: study more deeply specific topics	1, 2, 3, 4, 5	20	

Continuous Assessment (%)

70

Examination (%)

30

Examination Duration (Hours)

3

Assessment Rubrics (AR)**Assessment Task**

Participation (Applicable to students admitted in Semester A 2022/23 and thereafter)

Criterion

Ability to follow the lectures actively, with questions

Excellent

(A+, A, A-): High

Good

(B+, B): Significant

Marginal

(B-, C+, C): Basic

Failure

(F): Not even reaching marginal levels

Assessment Task

Exercises (Applicable to students admitted in Semester A 2022/23 and thereafter)

Criterion

Ability to understand and use the concepts and methods

Excellent

(A+, A, A-): High

Good

(B+, B): Significant

Marginal

(B-, C+, C): Basic

Failure

(F): Not even reaching marginal levels

Assessment Task

Projects in groups (Applicable to students admitted in Semester A 2022/23 and thereafter)

Criterion

Ability to study a specific domain within a group

Excellent

(A+, A, A): High

Good

(B+, B): Significant

Marginal

(B-, C+, C): Basic

Failure

(F): Not even reaching marginal levels

Assessment Task

Test (Applicable to students admitted in Semester A 2022/23 and thereafter)

Criterion

Understanding of lectures

Excellent

(A+, A, A-): High

Good

(B+, B): Significant

Marginal

(B-, C+, C): Basic

Failure

(F): Not even reaching marginal levels

Assessment Task

Participation (Applicable to students admitted before Semester A 2022/23)

Criterion

Ability to follow the lectures actively, with questions

Excellent

(A+, A, A-): High

Good

(B+, B, B-): Significant

Marginal

(B-, C+, C): Basic

Failure

(F): Not even reaching marginal levels

Assessment Task

Exercises

Criterion

Ability to understand and use the concepts and methods

Excellent

(A+, A, A-): High

Good

(B+, B, B-): Significant

Fair

(C+, C, C-): Moderate

Marginal

(D): Basic

Failure

(F): Not even reaching marginal levels

Assessment Task

Projects in groups

Criterion

Ability to study a specific domain within a group

Excellent

(A+, A, A-): High

Good

(B+, B, B-): Significant

Fair

(C+, C, C-): Moderate

Marginal

(D): Marginal

Failure

(F): Not even reaching marginal levels

Assessment Task

Test (Applicable to students admitted before Semester A 2022)

Criterion

Understanding of lectures

Excellent

(A+, A, A-): High

Good

(B+, B, B-): Significant

Fair

(C+, C, C-): Moderate

Marginal

(D): Basic

Failure

(F): Not even reaching marginal levels

Part III Other Information

Keyword Syllabus

- Machine Learning
- Optimisation
- Control Theory
- Dynamic Systems
- Dynamic Programming
- Stochastic Control
- Markov Decision Processes
- Markov Chains
- Gradient- Stochastic Gradient

Reading List

Compulsory Readings

Title	
1	Lecture Notes and Slides

Additional Readings

Title	
1	Y. LeCunn, Y. Bengio & G. Hinton, “Deep Learning” , Nature, 521 (7553): 436-444, (2015).
2	Q.Li, L.Chen,C.Tai,W.E, Maximum Principle Based Algorithm for Deep Learning, Journal of Machine Learning Research,18 (2018),1- 29
3	A, Chiuso , G. Pillonetto, System Identification: A Machine Learning Perspective, Annual Review of Control, Robotics and Autonomus Systems, (2019), 2-281-304
4	A. Bensoussan, F. Gelir, V. Ramakrishna, M-B.Tran, Identification of Linear Dynamical Systems and Machine Learning Journal of Convex Analysis, 28 (2), 2021