# SDSC8014: ONLINE LEARNING AND OPTIMIZATION

**Effective Term**
Semester B 2024/25

## Part I Course Overview

**Course Title**
Online Learning and Optimization

**Subject Code**
SDSC - Data Science
**Course Number**
8014

**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**

This course covers the fundamentals and applications of online learning and optimization. Topics include online learning, online convex optimization, competitive analysis, regret analysis, online gradient descent, and online algorithms. Other selective topics include online optimization with prediction, robust optimization, online stochastic optimization, and online optimization with feedbacks. Applications in online learning and optimization in societal systems in the face of input uncertainty will be used to complement the theoretical developments. Students should know about convex optimization, linear algebra, and calculus.

**Course Intended Learning Outcomes (CILOs)**

| | CILOs | Weighting (if app.) | DEC-A1 | DEC-A2 | DEC-A3 |
|---|---|---|---|---|---|
| 1 | Describe the fundamentals of key online optimization frameworks | 20 | x | | |
| 2 | Describe the basic theory and solution methodologies for online learning and key online optimization approaches | 40 | x | | |
| 3 | Compare and analyze different online optimization approaches | 15 | x | x | |
| 4 | Apply key online optimization frameworks to solve practical problems | 25 | x | x | 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 lectures to gain knowledge about online learning and optimization | 1, 2, 3, 4 | 30 hours in total |

| | | | | |
|---|---|---|---|---|
| 2 | Class-project | The students will identify and tackle practical problems in various engineering systems, ideally with online learning and optimization techniques learned from the course. The students will write a report and give two presentations. This learning activity will be mainly student-led but with the instructor's structural guidance. | 1, 2, 3, 4 | 30 hours in total 9 hours for in-class check-point presentation and final presentation, as well as after-class project activities |

**Assessment Tasks / Activities (ATs)**

| | ATs | CILO No. | Weighting (%) | Remarks (e.g. Parameter for GenAI use) |
|---|---|---|---|---|
| 1 | Paper Reading<br>Review reports of selected papers will show how well the students can understand the concepts, fundamental theory analysis, solution methods, and applications of online learning and optimization. This assessment will also train the students' ability for critical thinking and carrying out scientific reviews for academic works. | 1, 2, 3 | 25 | |
| 2 | Test<br>Questions are designed for the first part of the course to see how well the students have learned the basic concepts, fundamental theory analysis, solution methods, and applications of online learning and optimization. | 1, 2, 3, 4 | 25 | |
| 3 | Mini-Project<br>The project provides students chances to demonstrate how well they have achieved their intended learning outcomes. | 1, 2, 3, 4 | 25 | |

| | | | | |
|---|---|---|---|---|
| 4 | Mini-Project Presentation<br><br>The project provides students chances to demonstrate how well they have achieved their intended learning outcomes. | 1, 2, 3, 4 | 25 | |

**Continuous Assessment (%)**

100

**Examination (%)**

0

**Minimum Continuous Assessment Passing Requirement (%)**

0

**Minimum Examination Passing Requirement (%)**

0

**Assessment Rubrics (AR)**

**Assessment Task**

Paper Reading (for students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

**Criterion**

Ability to understand and the basic concepts, fundamental theory analysis, solution methods, and applications of online learning and optimization.

**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

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**Assessment Task**

Test (for students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

**Criterion**

Ability to understand and apply the basic concepts, fundamental theory analysis, solution methods, and applications of online learning and optimization.

**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

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**Assessment Task**
Mini-Project Report (for students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

**Criterion**
Ability to demonstrate the understanding of the basic concepts, fundamental theory, analysis and solution methods of online optimization in practical problems.

**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

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**Assessment Task**
Mini-Project Presentation (for students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

**Criterion**
Ability to demonstrate how well the intended learning outcomes are achieved.

**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

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**Assessment Task**

Paper Reading (for students admitted from Semester A 2022/23 to Summer Term 2024)

**Criterion**

Ability to understand and the basic concepts, fundamental theory analysis, solution methods, and applications of online learning and optimization.

**Excellent**

(A+, A, A-) High

**Good**

(B+, B) Significant

**Marginal**

(B-, C+, C) Moderate to basic

**Failure**

(F) Not even reaching marginal levels

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**Assessment Task**

Test (for students admitted from Semester A 2022/23 to Summer Term 2024)

**Criterion**

Ability to understand and apply the basic concepts, fundamental theory analysis, solution methods, and applications of online learning and optimization.

**Excellent**

(A+, A, A-) High

**Good**

(B+, B) Significant

**Marginal**

(B-, C+, C) Moderate to basic

**Failure**

(F) Not even reaching marginal levels

---

**Assessment Task**

Mini-Project Report (for students admitted from Semester A 2022/23 to Summer Term 2024)

**Criterion**

Ability to demonstrate the understanding of the basic concepts, fundamental theory, analysis and solution methods of online optimization in practical problems.

**Excellent**

(A+, A, A-) High

**Good**
(B+, B) Significant

**Marginal**
(B-, C+, C) Moderate to basic

**Failure**
(F) Not even reaching marginal levels

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**Assessment Task**
Mini-Project Presentation (for students admitted from Semester A 2022/23 to Summer Term 2024)

**Criterion**
Ability to demonstrate how well the intended learning outcomes are achieved.

**Excellent**
(A+, A, A-) High

**Good**
(B+, B) Significant

**Marginal**
(B-, C+, C) Moderate to basic

**Failure**
(F) Not even reaching marginal levels

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**Assessment Task**
Participation (for students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

**Criterion**
Ability to follow the lectures actively, with questions

**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

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**Assessment Task**

Exercises (for students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

**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

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**Assessment Task**
Projects in groups (for students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

**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) Basic

**Failure**
(F) Not even reaching marginal levels

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**Assessment Task**
Test (for students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

**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

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**Assessment Task**
Participation (for students admitted from Semester A 2022/23 to Summer Term 2024)

**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

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**Assessment Task**
Exercises (for students admitted from Semester A 2022/23 to Summer Term 2024)

**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

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**Assessment Task**
Projects in groups (for students admitted from Semester A 2022/23 to Summer Term 2024)

**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

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**Assessment Task**
Test (for students admitted from Semester A 2022/23 to Summer Term 2024)

**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

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# Part III Other Information

**Keyword Syllabus**
Online learning, online optimization, online algorithm, competitive analysis, regret analysis

**Reading List**

**Compulsory Readings**

| | Title |
|---|---|
| 1 | Elad Hazan (2016), "Introduction to Online Convex Optimization", Foundations and Trends® in Optimization: Vol. 2: No. 3-4, pp 157-325. http://dx.doi.org/10.1561/2400000013 (Selected chapters) |
| 2 | Allan Borodin and Ran El-Yaniv (2015), “Online Computation and Competitive Analysis”, Cambridge University Press New York, NY, USA (Selected chapters) |

**Additional Readings**

| | Title |
|---|---|
| 1 | Niv Buchbinder and Joseph (Seffi) Naor (2009), "The Design of Competitive Online Algorithms via a Primal–Dual Approach", Foundations and Trends® in Theoretical Computer Science: Vol. 3: No. 2–3, pp 93-263. http://dx.doi.org/10.1561/0400000024 |

| | |
|---|---|
| 2 | Shai Shalev-Shwartz (2011), “Online Learning and Online Convex Optimization”, Foundations and Trends® in Machine Learning, vol 4, no 2, pp 107–194, 2011. |
| 3 | Sébastien Bubeck and Nicolò Cesa-Bianchi (2012), "Regret Analysis of Stochastic and Nonstochastic Multi-armed Bandit Problems", Foundations and Trends® in Machine Learning: Vol. 5: No. 1, pp 1-122. http://dx.doi.org/10.1561/2200000024 |