ఆంధ్రప్రదేశ్ కేంద్రీయ విశ్వవిద్యాలయం
आंध्रप्रदेश केंद्रीय विश्वविद्यालय
Central University of Andhra Pradesh
Jnana Seema, Ananthapuramu

School of Interdisciplinary and Applied Sciences

Department of Mathematics and Computing

Vidya Dadati Vinayam
(Education Gives Humility)

PG Diploma in Mathematics for Machine Learning and Data Science

With effect from Academic Year 2025-2026

CONTENTS

PG Diploma in Mathematics for ML and DS

Introduction to the Programme

The Department of Mathematics and Computing, Central University of Andhra Pradesh, offers a one-year online PG Diploma certification programme in Mathematics for Machine Learning and Data Science from the academic year 2025-26. The main aim of introducing this programme is to provide strong Mathematical Foundations for UG/PG/Ph.D. students from different disciplines who are looking to build a career in the fields of Machine Learning (ML) and Data Science (DS). The courses in this programme are designed in view of the growing importance of mathematics and computer science, especially novel importance in many applications of ML and DS. The curriculum is carefully crafted to reflect the increasing relevance of both mathematics and computer science, focusing on key topics such as Artificial Intelligence (AI), Deep Learning (DL), ML, and DS. Students will also engage in programming courses that progress from foundational concepts to advanced applications, along with project work that exposes them to cutting-edge research in AI and ML.

The programme offers a range of features designed to enhance learning, including expert-led sessions on advanced applications in ML and DS and online programming assessments throughout the PG Diploma course.

By the end of the program, graduates will be poised to apply their knowledge to tackle complex problems in ML and DS, paving the way for further academic pursuits or promising careers in software industries and research and development organizations, often with competitive salary packages. Enroll now to embark on an exciting journey in these dynamic fields.

Programme Structure

S. No.	Course Code	Title of the Course	Credit Points	Credit Distribution		
				L*	T*	P*
Semester-I						
1	PDMLD101	Calculus for Machine Learning	4	3	1	-
2	PDMLD102	Matrix Methods in Machine Learning	4	2	1	1
3	PDMLD103	Introduction to Python Programming	4	2	-	2
4	PDMLD104	MOOC/NPTEL#	3	2	1	-
5	PDMLD105	MOOC/NPTEL#	3	2	1	-
6	PDMLD106	Case Study/MOOC#	2	1	1	-
		Total	**20**	**12**	**5**	**3**
Semester-II						
1	PDMLD201	Optimization Techniques in Machine Learning	4	2	1	1
2	PDMLD202	Data Science: Theoretical and Practical Perspective	4	2	-	2
3	PDMLD203	MOOC/NPTEL#	3	2	1	-
4	PDMLD204	MOOC/NPTEL#	3	2	1	-
5	PDMLD205	*Project Work	6	-	-	6
		Total	**20**	**8**	**3**	**9**

Note: L*: Lectures; **P*:** Practical's; **T*:** Tutorials

   *: Project/Dissertation work is compulsory and have to submit to the department one week before the second semester end examinations. Department faculty will allot a supervisor to each student at the end of first semester.

Note: 1. MOOCs are chosen by the student based on the availability of the courses offered on SWAYAM & other related platforms as suggested/recommended by the Department.

   2. The desired changes may be made by the Department in the programme structure as and when necessary with the prior approval of the BOS.

Credit Distribution

Semester	Total Credits
Semester-I	20
Semester-II	20
Total	**40**

Important Information to the Student

I. **Eligibility:**
(i) Students who have either completed UG or pursuing/completed PG/Ph.D. from the recognized institute/university can enroll for this programme.
(ii) Students of Central University of Andhra Pradesh (CUAP) either completed UG or pursuing/completed PG/Ph.D. can also enroll for this programme.
(v) Non CUAP students shall have to appear for an Entrance Examination conducted by the University.
(vi) A student can enroll for as many PG Diploma Programmes as he/she wishes.

II. **Selection Process:** Through CUAP diploma entrance examination.

III. **Duration of the Programme:** The minimum duration for completion of this programme is two semesters (one academic years) and the maximum duration of completion of programme is two years.

IV. **Attendance:** A student should have minimum 75% attendance in classes, seminars, practical/ lab in each course of study without which he/she will not be allowed for the semester end examination.

V. **Examination:**
(i). All theory courses in the programme shall have Continuous Internal Assessment (CIA) component of 40 marks and a Semester-End component of 60 marks. The minimum pass marks for a course is 50%.
(ii). The student has to appear 3 CIA tests of 15 marks each per semester in each course from which the best 2 performances shall be considered for the purpose of calculating the marks. A record of the continuous assessment is maintained by the department. The remaining 10 marks are awarded based on participation and performance in:
- Assignments
- Class presentations/Seminar
- Quizzes

(iii). A student should pass separately in both CIA and the Semester End Examination.
(iv) Semester-end examination shall consist of objective type questions, descriptive type questions, short answer questions and case studies or any other formats.
(v) A student failing to secure the minimum pass marks in the CIA is not allowed to take the end semester examination of that course. She/He has to redo the course by attending special classes for that course and get the pass percentage in the internal tests to become eligible to take the semester end examination.
(vi) Students failing a course due to lack of attendance should redo the course.

Semester – I

Course Code**: PDMLD101** No. of Credits**: 4** Total Hours: **60**	**Calculus for Machine Learning**

Course Objectives

- Provide a foundational understanding of multivariable calculus and its applications in machine learning.
- Explore approximation theory, Taylor series expansions, and convex optimization techniques relevant to machine learning models.
- Demonstrate practical applications of calculus in machine learning algorithms such as gradient descent, backpropagation, and support vector machines.

Learning Outcomes

Upon completion of the course, students should be able to:
- Apply multivariable calculus techniques to analyze and optimize machine learning models.
- Utilize approximation methods such as Taylor series and Lagrange multipliers to solve optimization problems in AI and ML.
- Analyze convex functions and convex sets, understanding their role in optimization problems.
- Implement gradient-based optimization methods, including gradient descent and backpropagation, for training machine learning models.
- Evaluate the mathematical principles behind SVMs and maximum margin hyperplanes, utilizing Lagrange multipliers in model construction.

Course Outline

Unit-I: Foundations   13 Hours
Functions, Limits of Functions of Single Variables, Continuity, Derivatives of Functions of Single Variables, Relation of Continuity with Function Derivatives, Applications of Derivatives in Optimization, The Relation Between Differential and Integral Calculus, Fundamental Theorem of Calculus, Applications of Integration in Machine Learning.

Unit-II: Multivariable Calculus   15 Hours
Continuity and Derivatives of Multivariate Functions, Derivation and Integration of Vector Valued Functions, Gradient Vectors in Machine Learning, Chain Rule, Jacobian Matrix and it's Uses in Machine Learning, Hessian Matrix and Discriminants.

Unit-III: Approximation Theory of Functions of Several Variables   12 Hours
Approximation of Known and Unknown Functions, Taylor's Series Expansion and it's Applications, Method of Lagrange Multipliers for Maximization problems.

Unit-IV: Basic Theory for Convex Optimization   4 Hours
Convex Sets and Convex Functions, Properties of Convex Functions. Applications of convex optimization.

Unit-V: Applications of Machine Learning   16 Hours
Gradient Descent and Ascent Methods, Finding the Gradient by backpropagation, Matrix Form of Gradient Equations, Support Vector Machine (SVM), Maximum Margin Hyper Plane, Role of Lagrange Multipliers in Building the Model for Support Vector Machines.

References
1. Stefania, C., and Mehreen, S. "*Calculus for Machine Learning Understanding the Language of Mathematics*". Machine Learning Mastery.
2. James, S. *"Multivariable Calculus"*. Brooks/Cole Cengage Learning.
3. Sudhir, R. G., and Balmohan, V. L. *"A Course in Multivariable Calculus and Analysis"*. Springer.
4. Peter, F., Alvaro, F., Ajinkya, S. K., et all. "*The Statistics and Calculus with Python Workshop: A Comprehensive Introduction to Mathematics in Python for Artificial Intelligence Application".* Packt Publishing.

<table>
<tr><td>Course Code: PDMLD102
No. of Credits: 4
Total Hours: 60</td><td>Matrix Methods in Machine Learning</td></tr>
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Course Code: **PDMLD102** No. of Credits: **4** Total Hours: **60**	**Matrix Methods in Machine Learning**

Course Objectives

- Provide a rigorous understanding of vector spaces, linear transformations, and their foundational role in machine learning and data science.
- Explore matrix eigenvalues, eigenvectors, and sensitivity analysis, including their applications in optimization and stability analysis.
- Analyze the various applications of Singular Value Decomposition (SVD), Principal Component Analysis (PCA), and Low Rank Approximation (LRA) in data analytics, artificial intelligence and machine learning.

Learning Outcomes

After completion of the course student should be able to:
- Solve the linear system of equations using different matrix factorization methods like LU and QR decompositions.
- Analyze the sensitivity and stability of linear systems using matrix norms and condition numbers. Furthermore, apply these ideas in various real-life applications
- Implement least squares methods, including pseudo-inverse solutions, for data fitting and machine learning applications
- Utilize SVD for dimensionality reduction, PCA, and recommendation systems for OTT and ecommerce platforms.

Course Outline

Unit-I: Vector Spaces and Linear Transformations   15 Hours
Introduction to Vector Spaces, Subspaces, Linear Independence and Dependence of vectors, Basis and Dimensions, Linear transformations and its properties, Affine Transformation and its Properties, Difference Between Linear Transformation and Affine Transformation

Unit-II -Elementary Matrix Theory and Decompositions   15 Hours

Matrix form of System of Linear Equations, Existence and Uniqueness of the system $\mathbf{A}x = \mathbf{b}$, Triangular Systems, LU Decomposition, Rotators, Reflectors, QR Decomposition, Solving System of Linear Equations using QR Decomposition.

Unit-III - Matrix Eigen Values and Eigen Vectors: 9 Hours
Procedure of Finding Eigen Values and Eigen Vectors of a Square Matrix, Similar Matrices, Diagonalization, Special Matrices and Properties, Spectral Value Decomposition of Symmetric Matrices.

Unit-IV - Sensitivity Analysis for the System of Linear Equations   6 Hours
Matrix Norms, Sensitivity Analysis, Condition Number of a Matrix, Least Square Problem, Solution of Least Squares Problem using Pseudo Inverse.

Unit-V - SVD and it's Applications in Machine Learning   15 Hours
Singular Value Decomposition (SVD) of a Matrix, Properties of SVD, Low Rank Approximation, Principal Component Analysis, Relation Between SVD and Least Squares Problem, Recommendations design and rating prediction.

References

1. Deisenroth, M.P., Faisal, A.A., and Ong, C.S. *" Mathematics for Machine Learning"*. Cambridge University Press.
2. Peter, J. and Olever Shakiban, C. "*Applied Linear Algebra*". Prentice Hall.
3. Gilbert, S. "*Linear Algebra and Learning from Data*". Wellesley Cambridge Press.
4. Steven, J. L. "*Linear Algebra with Applications*". Pearson.
5. Trefethen and Bau . "*Numerical Linear Algebra*". Society for Industrial and Applied Mathematics.

Course Code: PDMLD103 No. of Credits: 4 Total Hours: 60	**Introduction to Python Programming**

Course Objectives:

- To introduce the basics of Python programming relevant to data analysis.
- To provide hands-on experience with Python libraries such as NumPy, Pandas, and Matplotlib.
- To prepare students to handle, manipulate, and visualize data using Python.

Learning Outcomes

After completing this course, students will be able to:
- Write Python programs using variables, functions, loops, and file operations.
- Perform data analysis using NumPy arrays and Pandas Data Frames.
- Create basic data visualizations using Matplotlib for data interpretation.

Unit I - Fundamentals of Python Programming   **15 Hours**

Basic Data Types, Conditional Statements, loops, Comments, Simple input-output, Type conversion, Operators, Built-in methods of data types.

Unit II - Functions   **14 Hours**

Creating Functions, Arguments. *Files and Input/output***:** File Objects, File Built-in Function.

Unit III - *NumPy*   **8 Hours**

Basics of NumPy arrays, Indexing & Operations on Arrays.

Unit IV - Pandas   **8 Hours**

Series, Data Frames, Reading CSV, Excel, Data Manipulation with Pandas.

Unit V - *Plotting and Visualization*   **15 Hours**

Importing Matplotlib, Line plots, Scatter plots, Customization: Title & Axis labels, Adding Legend, Annotations, Plot Styles: Histograms, Bar Graphs, Box and Whisker Plots.

References:

1. Mark, L. "*Learning Python*". O'Reilly Media.
2. Wes, M. "*Python for Data Analysis*". O'Reilly Media.
3. Joel, G. "*Data Science from Scratch*" O'Reilly Media.
4. Official documentation and tutorials:
    - NumPy: https://numpy.org/doc/
    - Pandas: https://pandas.pydata.org/docs/
    - Matplotlib: https://matplotlib.org/stable/contents.html

SEMESTER-II

Course Code : **PDMLD201** No. of Credits **: 4** Total Hours: **60**	**Optimization Techniques in Machine Learning**

Course Objectives

- Formulate and solve optimization problems using appropriate mathematical techniques.
- Apply linear and nonlinear programming techniques to data science problems.
- Analyze the convergence and complexity of optimization algorithms.
- Use optimization tools and apply optimization techniques in machine learning, operations research, and engineering domains.

Learning Outcomes
Upon completion of the course, students should be able to:

- Formulate optimization problems for real-world engineering and computational tasks.
- Solve linear programming problems using the Simplex method and its variants.
- Implement heuristic algorithms such as Genetic Algorithms and Particle Swarm Optimization.
- Analyze and apply convex optimization methods in machine learning and data science applications.

Course Outline

Unit I: Introduction to Optimization   15 Hours
Definition and types of Optimization Problems, Optimality Criteria and Basic Concepts, Formulation of Optimization Problems, Applications in Data Science, and machine learning.

Unit II: Linear Programming   16 Hours
Linear programming problem (LPP) formulation, Simplex method, Big-M and Two-phase methods, Duality theory and sensitivity analysis, Transportation and Assignment problems.

Unit III: Nonlinear Programming   8 Hours
Unconstrained optimization: Gradient descent, Newton's method, Conjugate Gradient method.

Unit IV: Constrained Optimization   8 Hours
Lagrange multipliers, Karush-Kuhn-Tucker (KKT) conditions, Penalty and barrier methods.

Unit V: Convex Optimization and Advanced Topics   13 Hours
Convex sets and functions, convex optimization problems, Duality in convex optimization, Introduction to Stochastic Optimization and Gradient-based optimization in ML (e.g., SGD, Adam).

References

1. Dimitri, P. B. *"Nonlinear Programming"*. Athena Scientific.
2. Stephen, B. and Lieven, V. *"Convex Optimization-Part 1"*, Cambridge University Press
3. Kalyanmoy, D. *"Optimization for Engineering Design: Algorithms and Examples",* PHI.

Course Code : PDMLD202 No. of Credits : 4 Total Hours: 60	**Data Science: Theoretical and Practical Perspective**

Course Objectives:

- To introduce the fundamental concepts, roles, and applications of data science.
- To provide essential techniques for data collection, preprocessing, and transformation.
- To enable students to perform basic exploratory data analysis and interpret statistical summaries.

Learning Outcomes:

After completing this course, students will be able to:

- Explain the data science process and identify key data science roles and applications.
- Apply data preprocessing techniques such as cleaning, integration, and transformation.
- Analyze datasets using descriptive statistics and visualize them effectively.
- Perform correlation and simple regression analysis for data interpretation.

Unit-I : Data Science   **15 Hours**
Introduction to Data Science, Data Science Roles, Applications of Data Science in various fields, Data Science Process: Overview, Defining Research goals, Retrieving data, Types of Data.

Unit -II - Data Collection and Data Pre-processing   **15 Hours**
Data Collection Strategies – Data Pre-Processing Overview – Data Cleaning – Data Integration and Transformation – Data Reduction – Data Discretization.

Unit-III - Describing Data   **8 Hours**
Describing Data with Tables and Graphs, Describing Data with Averages, Describing Variability.

Unit-IV - Distributions   **16 Hours**
Normal Distributions and Standard (z) Scores, Combining and Merging Data Sets, Reshaping and Pivoting, Data Transformation.

Unit-V - Exploratory Data analysis   **14 Hours**
Univariate, Bivariate, Multivariate Analysis, Descriptive Statistics, Correlation, Scatter plots, Coefficient of Correlation, regression line, least squares regression line.

References:

1. Gareth, J., Daniela, W., Trevor, H., and Robert, T. "*An Introduction to Statistical Learning*". Springer.
2. Foster, P. and Tom, F. "*Data Science for Business: What You Need to Know about Data Mining and Data-Analytic Thinking*" O'Reilly Media.
3. Peter, B. and Andrew, B. "*Practical Statistics for Data Scientists*" O'Reilly Media.
4. Jake, V. P. "*Python Data Science Handbook*" O'Reilly Media.
5. John, T. "*Exploratory Data Analysis*" Addison-Wesley.