

Mathematical modelling: Analysis and applications

Submitted in partial fulfilment of the required for the award of
Master of Science Degree in Bioinformatics and Data Science

By

Durgadevi J(43739004)



**DEPARTMENT OF BIOINFORMATICS AND DATASCIENCE
SCHOOL OF BIO AND CHEMICAL ENGINEERING**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with Grade "A" by NAAC | 12B Status by UGC |

Approved by AICTE

**JEPPIAAR NAGAR, RAJIV GANDHI SALAI,
CHENNAI - 600 119**

April – 2024



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DEPARTMENT OF BIOINFORMATICS AND DATA SCIENCE

BONAFIDE CERTIFICATE

This is to certify that this Project Report is the Bonafide work of **Durgadevi.J (43739004)** who carried out the project entitled **"Mathematical modelling: Analysis and application"** under my / our supervision from January 2024 to April 2024.

Internal Guide

External Guide (if Applicable)

Head of the Department

Submitted for Viva voce Examination held on _____

Internal Examiner

External Examiner

DECLARATION

I, **DURGADEVI J** hereby declare that the project entitled “Mathematical modelling: Analysis and applications” **done** by me under the guidance of **PROF.AMEEYA KUMAR NAYAK** is submitted in partial fulfilment of the requirements for the award of Master of Science degree in Bioinformatics and Data Science.

DATE:

DURGADEVI J

PLACE: CHENNAI

SIGNATURE OF THE CANDIDATE

ACKNOWLEDGEMENT

I am pleased to acknowledge my sincere thanks to the **Board of Management of SATHYABAMA** for their kind encouragement in doing this project and for completing it successfully. I am grateful to them.

I convey my thanks to **DR. REKHA CHAKRAVARTHI M.E., Ph.D. Dean of Arts and Science** for providing me necessary support and details at the right time during the progressive reviews.

I would like to express my sincere and deep sense of gratitude to my project guide

MS. Manisha koyimadatha Department of Bioinformatics and Data Science for his valuable guidance, suggestions, and constant encouragement that paved way for the successful completion of my project work.

I wish to express my thanks to all Teaching and Non-teaching staff members of the **Department of Bioinformatics and Data Science** who were helpful in many ways for the completion of the project.

TABLE OF CONTENTS

S.NO	TOPIC	COURSES	PG NO
1	NPTEL Course	Mathematical Modelling: Analysis and Application	1
2	Review article	Navigating the multi-omics landscape: integration and analysis strategies	4
3	MATLAB courses	• MATLAB Onramp 13 • MATLAB Fundamentals 14 • Machine Learning Onramp 15 • App Building Onramp 16 • Object - Oriented Programming 17 • Computer Vision Onramp 18 • Reinforcement Learning Onramp 19 • Machine Learning with MATLAB 20 • MATLAB for Data Processing And Visualization 21 • Deep Learning with MATLAB 22 • Deep Learning Onramp 23	

		• MATLAB Programming Techniques	24
		• Image Processing Onramp	25
		• Image Processing with MATLAB	26
		• Signal Processing with MATLAB	27
		• Simulink Onramp	28
		• Signal Processing Onramp	29
		• Solving Nonlinear Equations with MATLAB	30
		• Statistics Onramp	31

1. IIT CERTIFICATION COURSE(NPTEL)

MATHEMATICAL MODELLING: ANALYSIS AND APPLICATIONS

DESCRIPTION

Thus, the mathematical modelling is a process of representation of the system with help of mathematical formulas and the mathematical model is the structure obtained. Mathematical modelling is a method used to represent real-world systems and phenomena using mathematical structures, equations, and relationships. The purpose of mathematical modelling is to gain insights into the behaviour of these systems, make predictions, and understand how they may respond to changes in variables or conditions. In many cases, mathematical models are too complex to solve analytically. In such cases, numerical methods and computer simulations are used to approximate solutions and simulate the behaviour of the system over time. A mathematical model plays a vital role in analysis of the system which other models like physical, chemical, linguistic etc.

- Simulation on models rather experiments on actual system.
- Best way to understand the physical behaviour of the system.
- Economic way for measurements.
- Control on parameters.
- Allow us to predict the future nature which haven't been seen so far.

Course layout

WEEK 1: Overview of mathematical modelling, types of mathematical models and methods to solve the same; Discrete time linear models – Fibonacci rabbit model, cell-growth model, prey-predator model; Analytical solution methods and stability analysis of system of linear difference equations; Graphical solution – cobweb

diagrams; Discrete time age structured model – Leslie Model; Jury's stability test; Numerical methods to find eigen values – power method and LR method.

WEEK 2: Discrete time non-linear models- different cell division models, prey-predator model; Stability of non-linear discrete time models; Logistic difference equation; Bifurcation diagrams.

WEEK 3: Introduction to continuous time models – limitations & advantage of discrete time model, need of continuous time models; Ordinary differential equation (ODE) – order, degree, solution and geometrical significance; Solution of first order first degree ODE – method of separation of variables, homogeneous equation, Bernoulli equation; Continuous time models – model for growth of micro-organisms, chemostat; Stability and linearization methods for system of ODE's.

WEEK 4: Continuous time single species model – Allee effect; Qualitative solution of differential equations using phase diagrams; Continuous time models – Lotka Volterra competition model, prey-predator models.

SCOPE OF MATHEMATICAL MODELING IN BIOSCIENCES:

Specifically in bio-sciences, mathematical models are used to:

- **Diagnose and treatment of the disease (bio-medical).**

Mathematical models play a crucial role in understanding the dynamics of diseases, predicting their progression, and evaluating treatment strategies. For example, epidemiological models like the SIR (Susceptible-Infectious-Recovered) model can simulate the spread of infectious diseases within a population, aiding in the design of public health interventions.

- **Study the growth and shape of plants (botany).**

Mathematical modelling in botany helps elucidate the underlying mechanisms governing plant growth, development, and morphogenesis. Models can describe processes such as nutrient uptake, photosynthesis, hormonal regulation, and cell expansion.

- **Design artificial body parts (bio-engineering).**

Bioengineering involves the application of engineering principles to biological systems, including the design and fabrication of artificial organs, prosthetic limbs, and tissue-engineered constructs. Mathematical modelling plays a critical role in the design process by predicting the behaviour of biological materials and devices under various conditions.

- **Enzyme kinetics and chemical reactions in living bodies (biochemistry).**

Mathematical models are used in biochemistry to describe the kinetics of enzyme-catalyzed reactions and the dynamics of biochemical pathways within living organisms. These models can elucidate the mechanisms of enzyme-substrate interactions, enzyme inhibition, and allosteric regulation.

- **Survival of Population with limited resources (ecology) etc.**

Mathematical models in ecology help scientists understand the dynamics of populations, communities, and ecosystems in response to environmental changes and resource availability.

WHAT I LEARNT?

- Major content of this course is chosen from population dynamics. This course covers the fundamentals of deterministic models in both discrete and continuous time domain.
- This course includes both linear and non-linear models with sufficient amount of theoretical background.
- The relevant concepts and solution methods of various difference and differential equations are provided. We have also focused on graphical solution for clear analysis of nature of models.

COURSE DURATION

4 WEEKS

COURSE GRADE: 56%

2. REVIEW ARTICLE

Navigating the Multi-omics Landscape: Integration and Analysis Strategies

INTRODUCTION

Genomics, transcriptomics, proteomics, metabolomics, and epigenomics are just a few of the omics disciplines whose data must be integrated and analyzed extensively in order to successfully navigate the multi-omics environment. Biology has relied more and more on data generated at various levels—collectively referred to as "multi-omics" data—since the advent of sequencing technologies. The domains of biology and medicine have seen a complete transformation as a result of the increased opportunities for integrated system-level methods brought about by the availability of multi-omics data. In order to obtain a practical understanding of biological processes, multi-omics data analysis combined with clinical information is currently the main focus. Meta-analytic methods improve statistical power and robustness by combining findings from multiple studies. Researchers can generate hypotheses by exploring and interpreting multi-omics data with the help of interactive visualization tools. Ultimately, interdisciplinary teams of bioinformaticians, biologists, clinicians, and statisticians must collaborate to properly address complex multi-omics research problems and advance biological knowledge.

Methods for Integrating Genomic, Transcriptomic, and Metabolomic Data Sets

Achieving a comprehensive understanding of biological systems and understanding complex molecular interactions requires integration of genomic, transcriptomic, and metabolomic resources. To aid in this integration, several techniques have been devised, each with advantages and disadvantages. Identification of connections between different omics layers is often accomplished using correlation-based analysis. Interaction networks can be constructed, for example, to explore patterns of co-expression between genes and metabolites or between transcripts and metabolites.

Functional connections and critical regulatory nodes can be revealed through these networks by identifying modules or clusters of co-regulated molecules.

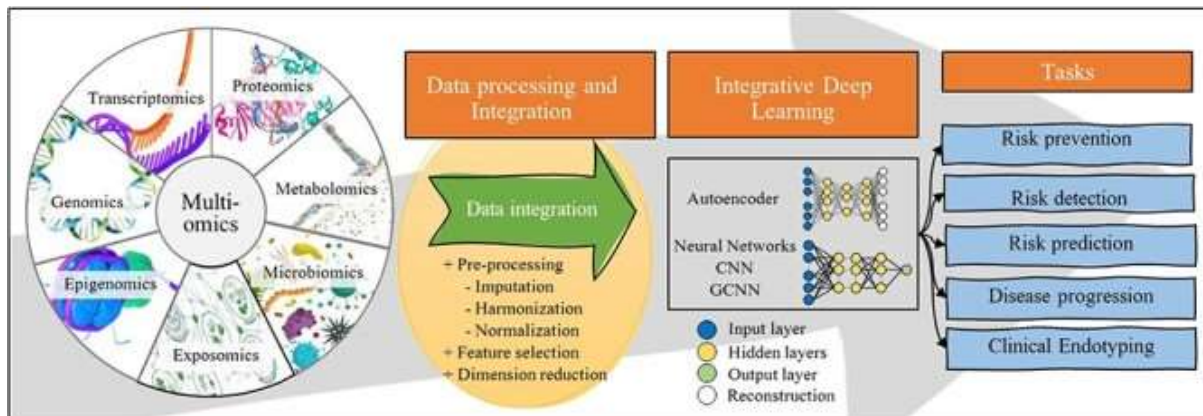
Transcriptome, metabolomic and genomic data are mapped onto biological pathways or networks as part of a different technique known as pathway-based studies. In specific biological situations, this makes it possible to detect synergistic changes at multiple omics levels. Metabolomics, the study of metabolic intermediates (metabolites) and tiny molecules (e.g., less than 1200 Da), has been applied extensively to the study of interactions between environmental stimuli and downstream products of genes and proteins. Metabolomics has been extensively employed in the last ten years to investigate a variety of pathophysiological processes, such as type 1 diabetes and cancer. The usual objectives of these studies are to find biomarkers that indicate the onset, prognosis, and monitoring of the effectiveness of treatment. Because of the metabolome's strong sensitivity to biological and environmental regulatory processes, analyzing it offers a special method for defining the organismal phenotype. Several software tools have been developed to aid in the integration of different omics datasets based on biochemical route, ontology, network, or empirical linkage. To synthesize heterogeneous omics data, machine learning techniques such as multi-omics data integration algorithms provide useful tools. By capturing complex interactions across multiple data sources, these techniques hope to reveal hidden patterns or interactions that conventional statistical methods might miss. Methods including canonical correlation analysis (CCA), partial least squares (PLS), and different clustering and classification algorithms can be used to efficiently combine genomic, transcriptomic, and metabolomic data.

Furthermore, network-based integration methods integrate omics data into the framework of biological networks using prior understanding of molecular interactions. Regulatory links between genes, transcripts and metabolites can be inferred and essential molecular actors can be prioritized by integrating omics data into network models. By combining gene expression data with biological domain information (such as biochemical pathways and biological processes), these techniques aid in the understanding of biological data.. Another interesting tool set for studying various organismal and cellular systems is network-based studies. Genes, proteins, and metabolites are only a few examples of the various types of cellular components that are connected in intricate ways through biological networks. These networks are

useful for mapping or integrating different omics experimental results and for identifying changed graph neighborhoods—neighborhoods that are not dependent on pre-established biochemical processes. SAMNetWeb and pw Omics make it possible to integrate data for biological network computation, visualization, and functional enrichment analysis from transcriptomics, proteomics, and interactomics. When biochemical domain knowledge is lacking, correlation-based methods can be helpful for integrating omics data and for integrating biological and other meta data (such as clinical outcomes).. Weighted Gene Correlation Network Analysis can be used to link highly related gene clusters to further data, including proteomic and clinical information, single-nucleotide polymorphisms (SNPs), and other information.

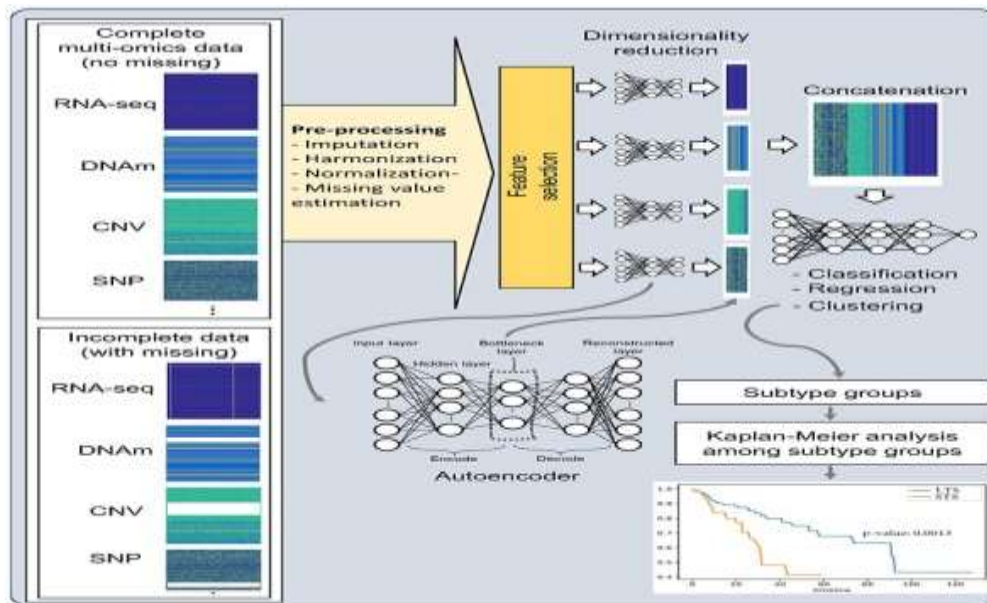
Deep Learning Approaches for Multi-omics Data Fusion

Deep learning techniques have become useful tools for integrating and evaluating multi-omics data, which includes many types of biological information, including transcriptomics, proteomics, metabolomics, and genomes. Using these techniques, a deeper understanding of biological systems can be obtained by imaging the complex connections and interactions between different omics layers. A popular method for combining multi-omics data is the use of neural networks, particularly deep learning frameworks. These designs are capable of processing high-dimensional data and capture complex relationships and patterns between different omics modalities. For example, Recurrent Neural Networks (RNNs) and Convolutional Neural Networks (CNNs) have been designed to handle time-series omics data and genomic sequences, respectively, making it possible to integrate different omics datasets.. Multi-omics data can be used to monitor progress, enhance prevention, early diagnosis, and prediction, decipher patterns and endotyping, and create customized treatment plans. With exceptional sensitivity, specificity, and speed, deep learning algorithms may incorporate many omics layers, such as clinical or health record data, in addition to analyzing each omics type independently. DL is an artificial intelligence technique that teaches itself without the need for predefined mathematical formulas or IF statements in programming. DL employs a higher number of hidden layers than standard Artificial neural network, which usually can only afford one or two hidden layers. The layer's capacity to recognize intricate patterns and make precise predictions increases with depth. DL is capable of encoding and learning in both supervised and unsupervised environments from heterogeneous and complex input.



Combining several omics data types may make it easier to understand the possible alterations that cause disease or may assist find new therapeutic targets for in-depth molecular research. Many openly accessible technologies have been created for the integration of omics data. DL's exceptional prediction accuracy is mostly attributed to its multi-layered neural network topologies, which enable it to automatically collect hierarchical and nonlinear representative characteristics. In biomedical research, the majority of deep learning (DL) methods have been used to classification and association problems, including protein categorization, gene expression regulation, protein prediction, and genome-wide association studies. These techniques have benefited from improved prediction accuracy. The majority of innovative deep learning models use vast amounts of data. Multiple forms of extremely high-dimensional biological data are involved in multi-omics data studies, but the data quantities are relatively smaller, which leads to a serious overfitting problem during model training. Developing a high-dimensional multi-omics data analytical data integration technique that can capture interaction effects and biological interpretation presents additional obstacles.

The majority of relevant research falls into one of the following categories: Multi-omics data-driven DL-based data integration research -selection/reduction of features, prediction of clinical outcomes, study of survival, and clustering for the identification of subtypes



To reduce noise and guarantee consistency, the data first goes through a thorough cleaning and preparation step. Then, dimensionality reduction techniques such as principal component analysis (PCA) or autoencoders are used to reduce the complexity of the data. Third, a sizable dataset is created by concatenating multi-omics variables for data integration. Fourth, additional strategies for feature reduction or selection are used. The integrated data are next examined for the intended uses, including clustering, regression, and classification.

Clinical and Translational Applications of Integrated Multi-omics Analysis

The prevalence of AD, the most prevalent neurological illness, has been rising annually. According to a global public health study, there would be over 150 million AD patients worldwide by 2050, up from the current 57 million, which will result in a large rise in medical and societal expenses. Though severe pathological alterations in AD have been shown by tau neurofibrillary tangles and amyloid ($A\beta$) plaques, For AD, there is currently no proven cure, and its pathophysiology remains unclear. Consequently, a thorough comprehension of the molecular pathways driving AD pathogenesis by multi-omics will contribute to the advancement of AD prognosis, treatment, and prevention. The pathophysiology of AD will be fully and methodically

revealed through the methodical fusion of disciplines includes the transcriptome, proteome, metabolome, and genome within multi-omics. Understanding the underlying causes of AD, such as high-risk mutant genes of Amyloid Precursor Protein, Presenilin-1, and other proteins, requires an understanding of genomics, the science of characterizing and measuring every gene and mutation in an organism. Additionally, it is capable of locating new loci that raise the risk of AD. A potent method for examining gene regulatory processes is transcriptomics, which can map transcriptional process genomes that are co-expressed linked with Alzheimer's disease symptoms. Proteomics investigates the function of proteins in AD through the study of post-translational changes, protein-protein interactions, and protein expression. Perhaps the most important molecular events in the course of AD are the alterations in hippocampus proteins connected to the electron transport chain in the mitochondria and insulin signalling. In general, multi-omics has a wide range of uses in the investigation of therapeutic targets and neurodegenerative biomarkers . As high-volume histology and integrating algorithms progress, Technologies utilizing multi-omics are expected to uncover more comprehensive modifications to the chemical network in neurodegenerative illnesses.

Interdisciplinary Collaboration in Multi-omics Data Research

Research on multi-omics data analysis requires the integration of information from multiple omics layers—genomics, transcriptomics, proteomics, metabolomics and epigenomics, biology, bioinformatics, computing, medicine, and statistics—by experts in various fields. ,collaborate successfully. Bioinformaticians develop methods and tools for data integration, analysis, and visualization, while biologists provide field knowledge, guide research direction, and interpret biological significance. Computer scientists build scalable infrastructure for data processing and storage, while statisticians ensure that reliable statistical techniques are used to derive valuable insights from complex datasets. In addition, clinicians provide insightful feedback on how clinically relevant and applicable the study results are. This collaborative strategy encourages creativity, accelerates research, and improves our understanding of complex biological processes and diseases, leading to tailored treatment and better patient outcomes. Furthermore, interdisciplinary collaboration allows scientists to develop a holistic analysis framework that accounts for the diversity and high complexity of multi-omics data. Interdisciplinary teams combining knowledge in data

science, statistics, and computational biology can develop complex algorithms and machine learning models tailored to the special characteristics of multi-omics datasets. These models enable the identification of biomarkers, regulatory networks, and biological pathways that underlie complex phenotypes and diseases. Beyond data analysis, interdisciplinary collaboration is critical to understanding the biological insights gained from multi-omics research. Biologists and clinicians bring critical domain-specific expertise to understanding the functional consequences of molecular changes observed in the data. Their expertise enables researchers to contextualize findings within the larger landscape of biological processes, pathways and disease mechanisms, therefore advancing our understanding of complex biological systems. Furthermore, the multidisciplinary collaboration involved the development of computational tools and software for multi-omics data analysis. Computer scientists, software engineers, and bioinformaticians collaborate to develop user-friendly, scalable, and flexible software packages that allow researchers to efficiently explore and analyze multi-omics datasets. Finally, interdisciplinary collaboration facilitates the application of research findings in clinical settings. Interdisciplinary teams may collaborate with industry partners, clinicians, and regulatory authorities to bring innovations to market, validate findings, establish diagnostic or therapeutic strategies, and negotiate the regulatory landscape.

Durgadevi J

ORIGINALITY REPORT

3%

SIMILARITY INDEX

2%

INTERNET SOURCES

2%

PUBLICATIONS

0%

STUDENT PAPERS

PRIMARY SOURCES

1

Kwanjeera Wanichthanarak, Johannes F. Fahrmann, Dmitry Grapov. "Genomic, Proteomic, and Metabolomic Data Integration Strategies", Biomarker Insights, 2015

Publication

1%

2

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5

Zhaoxiang Cai, Rebecca C. Poulos, Adel Aref, Phillip J. Robinson, Roger R. Reddel, Qing Zhong. "Transformer-based deep learning integrates multi-omic data with cancer pathways", Cold Spring Harbor Laboratory, 2024

Publication

<1%

3.MATLAB COURSES

Based on the MATLAB Certificate there are 19 courses I have completed

- MATLAB Onramp
- MATLAB Fundamentals
- Machine Learning Onramp
- App Building Onramp
- Object - Oriented Programming
- Computer Vision Onramp
- Reinforcement Learning Onramp
- Machine Learning with MATLAB
- MATLAB for Data Processing And Visualization
- Deep Learning with MATLAB
- Deep Learning Onramp
- MATLAB Programming Techniques
- Image Processing Onramp
- Image Processing with MATLAB
- Signal Processing with MATLAB
- Simulink Onramp
- Signal Processing Onramp
- Solving Nonlinear Equations with MATLAB
- Statistics Onramp

MATLAB COURSES

3.1 MATLAB ONRAMP

DESCRIPTION

The MATLAB Onramp course is an interactive and self-paced online tutorial designed to introduce newcomers to MATLAB, a powerful programming language and environment used extensively in engineering, mathematics, science, and beyond. Through a series of modules, learners are guided through the fundamental concepts and practical skills needed to start using MATLAB effectively. The course covers essential topics such as navigating the MATLAB environment, understanding basic syntax and programming concepts, working with variables, arrays, and matrices, creating plots and visualizations, and conducting basic data analysis.

WHAT I LEARNT?

- By the end of the course, learners should have a solid understanding of the MATLAB environment, syntax, and basic programming concepts. They will be able to navigate MATLAB confidently and write simple scripts to perform tasks like data analysis, visualization, and basic mathematical computations.
- MATLAB Onramp covers basic data analysis techniques, including manipulation of arrays and matrices, statistical calculations, and visualization of data.
- Completing the MATLAB Onramp serves as a solid foundation for diving into more advanced MATLAB topics and applications..

COURSE DURATION

2 HOURS

COURSE GRADE

100%

3.2 MATLAB FUNDAMENTALS

DESCRIPTION

A MATLAB Fundamentals course typically covers the essential aspects of using MATLAB for numerical computation, data analysis, and visualization. A MATLAB Fundamentals course is designed to provide participants with a comprehensive understanding of MATLAB's core concepts and functionalities. Through a structured curriculum, participants are introduced to the MATLAB environment, including its command-line interface and graphical tools, enabling them to navigate the software effectively. Advanced topics, such as specialized toolboxes and symbolic computation, may be introduced depending on the course's depth. Throughout the course, participants engage in hands-on projects and practical applications, cementing their understanding through real-world problem-solving.

WHAT I LEARNT?

- Develop proficiency in data analysis and visualization, learning how to import, manipulate, analyze, and present data effectively using MATLAB's powerful tools and functions.
- modularization and function creation, enabling them to write maintainable and optimized code.
- Depending on the course's depth, participants may also gain exposure to advanced topics such as specialized toolboxes and symbolic computation, expanding their knowledge and skill set

COURSE DURATION

16.5 HOURS

COURSE GRADE

100%

3.3 MACHINE LEARNING ONRAMP

DESCRIPTION

The Machine Learning Onramp course is a comprehensive introductory program designed to familiarize participants with the fundamental concepts and techniques of machine learning. The course begins with an overview of what machine learning is, its applications, and its importance in various industries. An introduction to neural networks and deep learning is provided, covering topics such as feedforward neural networks, convolutional neural networks (CNNs), and recurrent neural networks (RNNs).

WHAT I LEARNT?

- Participants will gain a solid understanding of the fundamental concepts, techniques, and algorithms used in machine learning. This includes supervised and unsupervised learning methods, data preprocessing techniques, model evaluation, and more.
- With a comprehensive understanding of core concepts such as supervised and unsupervised learning, coupled with proficiency in data preprocessing techniques and model evaluation, individuals gain the confidence to tackle real-world data challenges.
- Through hands-on projects and exercises, We develop the ability to apply machine learning algorithms using popular tools and libraries like scikit-learn, TensorFlow, or PyTorch.

COURSE DURATION

2 HOURS

COURSE GRADE

100%

3.4 APP BUILDING ONRAMP

DESCRIPTION

An App Building Onramp course is designed to provide individuals with the foundational knowledge and skills needed to develop mobile applications. Understanding how to create user-friendly interfaces is crucial in app development. Many apps require interaction with a server or database for data storage and retrieval. The course may cover basics of backend development, including APIs, databases, and server-side scripting. Participants are introduced to best practices in app development, including optimizing app performance, security considerations, and adhering to platform-specific guidelines.

WHAT I LEARNT?

- Many App Building Onramp courses emphasize collaboration and version control using tools like Git. We will learn how to work effectively in a team environment and manage code changes using version control systems.
- The course serves as a stepping stone for individuals who wish to pursue further learning and specialization in specific areas of app development, such as iOS or Android development, game development, or mobile app security
- By completing hands-on projects and assignments throughout the course, students will develop the skills necessary to build their own mobile applications, ranging from simple utility apps to more complex projects with database integration and server communication.

COURSE DURATION

1 HOUR

COURSE GRADE

100%

3.5 OBJECT - ORIENTED PROGRAMMING

DESCRIPTION

Through a combination of theoretical concepts and hands-on practical exercises, we delve into the principles and practices of OOP, learning to design, implement, and maintain robust and scalable software systems. The course typically covers key OOP concepts such as encapsulation, inheritance, and polymorphism, empowering students to organize code efficiently, enhance reusability, and facilitate easier maintenance. Moreover, students often explore advanced topics like design patterns, abstraction, and object relationships, gaining the skills necessary to develop complex applications and navigate real-world software development challenges

WHAT I LEARNT?

- The Object-Oriented Programming (OOP) course equips with a robust skill set and a deep understanding of software development principles.
- Upon completion, students emerge with the ability to design, implement, and maintain complex software systems using OOP concepts such as encapsulation, inheritance, and polymorphism. They gain proficiency in organizing code efficiently, enhancing reusability, and ensuring scalability.
- Developing problem-solving skills and learn to navigate real-world software development challenges by applying design patterns and leveraging abstraction

COURSE DURATION

2 HOURS

COURSE GRADE

100%

3.6 COMPUTER VISION ONRAMP

DESCRIPTION

The Computer Vision Onramp course is an introductory program designed to provide learners with a comprehensive understanding of computer vision concepts and techniques. The course usually starts with an overview of what computer vision is, its applications, and its significance in various fields such as healthcare, autonomous vehicles, robotics, etc. Learners are introduced to fundamental concepts such as image representation, colour spaces, image filtering, and feature extraction. These concepts lay the groundwork for understanding more advanced topics. The course covers various image processing techniques like edge detection, image segmentation, and morphological operations. These techniques are essential for preprocessing images before applying more advanced computer vision algorithms.

WHAT I LEARNT?

- Upon completing the Computer Vision Onramp course, participants emerge with a robust understanding of the fundamental principles and techniques underlying computer vision.
- Armed with this knowledge, we gain the ability to process and analyze images effectively, extracting meaningful information and insights.
- To become proficient in employing various image processing techniques, feature extraction methods, and object detection algorithms to tackle real-world challenges.

COURSE DURATION

2 HOURS

COURSE GRADE

100%

3.7 REINFORCEMENT LEARNING ONRAMP

DESCRIPTION

The Reinforcement Learning Onramp is a structured learning pathway designed to introduce individuals to the fundamentals of reinforcement learning (RL). It serves as a starting point for beginners who want to understand the principles, algorithms, and applications of RL in various fields such as artificial intelligence, robotics, game playing, and more. MDPs form the mathematical framework for modelling RL problems. The course covers MDPs, including states, actions, transition probabilities, and rewards. Deep RL integrates neural networks with RL algorithms to handle high-dimensional state spaces. The course introduces deep Q-networks (DQN), policy gradients, and actor-critic methods.

WHAT I LEARNT?

- Acquiring a comprehensive understanding of the fundamental concepts, principles, and terminology of reinforcement learning, including Markov Decision Processes (MDPs), value functions, policies, and exploration-exploitation trade-offs.
- Help us to develop problem-solving skills necessary to tackle real-world reinforcement learning problems across diverse domains such as robotics, gaming, finance, healthcare, and more. learnt how to formulate RL problems, choose appropriate algorithms, and evaluate their performance.
- The course will enhance learners' critical thinking abilities as they analyze and evaluate the performance of different RL algorithms in various scenarios.

COURSE DURATION

2 .5 HOURS

COURSE GRADE

100%

3.8 MACHINE LEARNING WITH MATLAB

DESCRIPTION

The "Machine Learning with MATLAB" course is an immersive educational experience designed to equip participants with the knowledge and skills necessary to excel in the dynamic field of machine learning. Through a combination of theoretical foundations and hands-on practical exercises, this course delves into various aspects of machine learning, from fundamental concepts to advanced techniques. This course covers the topics such as data preprocessing, feature selection, model evaluation, and algorithm implementation using MATLAB, a powerful computational tool widely used in the field of data science and machine learning

WHAT I LEARNT?

- Help us to Gain proficiency in utilizing MATLAB, a versatile computational tool, to develop, train, and deploy machine learning models for various real-world applications.
- With hands-on experience in data preprocessing, feature selection, model evaluation, and algorithm implementation, participants are equipped to tackle complex problems and make informed decisions in data-driven environments.
- Furthermore, acquiring the ability to interpret and communicate the results of machine learning models effectively, empowering them to contribute meaningfully to projects and initiatives across diverse industries.

COURSE DURATION

12 HOURS

COURSE GRADE

100%

3.9 MATLAB FOR DATA PROCESSING AND VISUALIZATION

DESCRIPTION

The "MATLAB for Data Processing and Visualization" course is designed to provide participants with a comprehensive understanding of how to utilize MATLAB, a powerful programming language and computing environment, for handling, analyzing, and visualizing data. The course begins with an overview of MATLAB's interface, basic syntax, and fundamental operations. Participants learn how to navigate the MATLAB environment, work with variables, and execute basic commands. The course covers a range of data analysis techniques available in MATLAB, including descriptive statistics, hypothesis testing, regression analysis, and clustering.

WHAT I LEARNT?

- This help us to learn how to create insightful visualizations of their data using MATLAB's plotting functions, including 2D and 3D plots, histograms, scatter plots, and more. They will also learn how to customize the appearance of their plots to effectively communicate their findings.
- Many courses include hands-on projects or assignments where participants apply their MATLAB skills to analyze real-world datasets and create meaningful visualizations.
- how to perform basic and advanced data analysis tasks using MATLAB, such as statistical analysis, curve fitting, signal processing, image processing, and machine learning.

COURSE DURATION

8 HOURS

COURSE GRADE

100%

3.10 DEEP LEARNING WITH MATLAB

DESCRIPTION

Deep learning is a branch of machine learning that teaches computers to do what comes naturally to humans: learn from experience. Deep learning uses neural networks to learn useful representations of features directly from data. The Deep Learning with MATLAB course provides a comprehensive introduction to deep learning concepts and techniques using MATLAB. With "Deep Learning with MATLAB," users can leverage a vast array of built-in algorithms and tools, including convolutional neural networks (CNNs), recurrent neural networks (RNNs), and generative adversarial networks (GANs). The intuitive graphical interface simplifies the process of model creation, allowing users to focus on experimentation and innovation rather than grappling with complex coding.

WHAT I LEARNT

- By harnessing deep learning algorithms within MATLAB's framework, researchers and practitioners have achieved remarkable outcomes. One notable area of impact is in image recognition and classification, where convolutional neural network (CNNs) have demonstrated unprecedented accuracy in identifying objects within complex visual scenes
- Deep learning with MATLAB has revolutionized medical image analysis, facilitating the detection of anomalies in MRI scans, X-rays, and histopathology slides. Researchers can leverage MATLAB's deep learning tools to create customized architectures tailored to specific medical imaging tasks, ultimately enhancing diagnostic accuracy and patient care.
- MATLAB's integration with specialized hardware platforms, such as GPUs and FPGAs, empowers researchers to accelerate deep learning computations.

COURSE DURATION

7 HOURS

COURSE GRADE

100%

3.11 DEEP LEARNING ONRAMP

DESCRIPTION

The Deep Learning Onramp course is designed to provide participants with a comprehensive introduction to deep learning, a subset of machine learning focused on neural networks and their applications. The course starts with an overview of what deep learning is, its applications, and its significance in modern AI. The course teaches how to build and train neural networks using popular frameworks like TensorFlow or PyTorch. Participants learn about different types of neural networks, including feedforward, convolutional, and recurrent networks.

WHAT I LEARNT?

- Many deep learning courses involve hands-on projects where students apply what they've learned to solve real-world problems. Completing these projects helps reinforce concepts and build a portfolio of work to showcase to potential employers.
- Completing a Deep Learning Onramp course can serve as a solid foundation for further study or employment in the field of deep learning and artificial intelligence. It can provide a starting point for more advanced courses or projects, or even entry-level positions in industries where deep learning expertise is valued.
- acquiring practical skills in implementing deep learning models using popular frameworks like TensorFlow or PyTorch. This may include tasks such as data preprocessing, model building, training, evaluation, and deployment.

COURSE DURATION

2 HOURS

COURSE GRADE

100%

3.12 MATLAB PROGRAMMING TECHNIQUES

DESCRIPTION

The MATLAB Programming Techniques course is designed to provide participants with a comprehensive understanding of MATLAB programming concepts and techniques. Throughout the course, students will learn how to efficiently utilize MATLAB for various computational tasks, data analysis, and visualization. MATLAB fundamental section covers fundamental concepts such as variables, arrays, data types, operators, and basic MATLAB syntax. Using MATLAB's powerful plotting functions to create various types of plots including 2D and 3D plots, histograms, and scatter plots for data visualization. Techniques for integrating MATLAB with other programming languages (e.g., C/C++, Python) and tools for collaborative development.

WHAT I LEARNT?

- Gaining a solid understanding of the MATLAB programming language, its syntax, and its various features.
- This course help us to develop algorithms and implement them in MATLAB for various applications, such as signal processing, image processing, control systems, and more.
- understanding the importance of documenting their code and results effectively, including writing clear comments and generating reports or presentations.
- learning techniques for optimizing MATLAB code to improve performance and efficiency, including vectorization, preallocation, and parallel computing.

COURSE DURATION

16 HOURS

COURSE GRADE

100%

3.13 IMAGE PROCESSING ONRAMP

DESCRIPTION

The Image Processing Onramp course is a comprehensive introduction to the fundamentals of image processing. Designed for beginners and those seeking to enhance their understanding of digital image manipulation, this course covers a wide range of topics including image acquisition, preprocessing techniques, filtering, segmentation, feature extraction, and image enhancement. Participants will gain hands-on experience through practical exercises using industry-standard software tools and programming languages commonly employed in image processing applications. professional in fields such as computer vision, medical imaging, or remote sensing, this course provides a solid starting point for further exploration and application of image processing techniques.

WHAT I LEARNT?

- Completing the Image Processing Onramp course can have numerous outcomes, depending on your goals and aspirations. To gain a solid understanding of the fundamental concepts and techniques used in image processing, equipping you with valuable knowledge applicable across various industries, from healthcare to robotics.
- This course can serve as a stepping stone for further exploration and specialization in fields like computer vision, machine learning, and artificial intelligence.
- Additionally, mastering image processing techniques can enhance your problem-solving skills, allowing you to tackle real-world challenges more effectively.

COURSE DURATION

2 HOURS

COURSE GRADE

100%

3.14 IMAGE PROCESSING WITH MATLAB

DESCRIPTION

Completing the Image Processing with MATLAB course offers participants a comprehensive understanding of image processing principles and practical skills in MATLAB implementation. Throughout the course, participants explore a wide range of topics, including image enhancement, filtering, segmentation, feature extraction, and object detection. Participants gain proficiency in MATLAB, mastering the tools and functions necessary for effective image processing. They learn how to manipulate and analyze images using MATLAB's built-in functions and toolboxes, such as the Image Processing Toolbox. Hands-on exercises and projects provide participants with valuable practical experience, allowing them to apply their newfound knowledge to real-world scenarios. Through these activities, participants develop the ability to enhance image quality, remove noise, segment objects, extract features, and detect objects of interest within images.

WHAT I LEARNT?

- Comprehensive understanding of fundamental concepts in image processing, including image enhancement, filtering, segmentation, feature extraction, and object detection.
- Image processing algorithms and techniques using MATLAB's built-in functions and toolboxes, such as the Image Processing Toolbox.
- Image processing techniques to a variety of domains, including medical imaging, remote sensing, computer vision, digital photography, and more.

COURSE DURATION

11 HOURS

COURSE GRADE

100 %

3.15 SIGNAL PROCESSING WITH MATLAB

DESCRIPTION

The Signal Processing with MATLAB course offers participants a comprehensive exploration of signal processing fundamentals and their implementation using MATLAB. Throughout the course, participants delve into a wide range of topics, including time-domain and frequency-domain analysis, filtering techniques, convolution, and spectral analysis. They gain a deep understanding of how signals are processed and analyzed in various domains, from audio and speech processing to image and biomedical signal processing. Hands-on exercises and projects provide participants with opportunities to reinforce their learning and apply signal processing techniques to real-world problems.

WHAT I LEARNT ?

- Completing the Signal Processing with MATLAB course empowers participants with a comprehensive understanding of signal processing principles and practical skills in MATLAB implementation.
- Throughout the course, participants delve into fundamental concepts such as time-domain and frequency-domain analysis, filtering, convolution, and spectral analysis. They gain proficiency in MATLAB, mastering the tools and functions necessary for effective signal processing.
- Hands-on exercises and projects provide participants with valuable practical experience, allowing them to apply their newfound knowledge to real-world scenarios.

COURSE DURATION

7.5 HOURS

COURSE GRADE

100 %

3.16 SIMULINK ONRAMP

DESCRIPTION

Completing the Simulink Onramp course is a significant milestone in mastering Simulink, a powerful tool for modelling, simulating, and analyzing dynamic systems. Throughout the course, participants embark on a journey to understand Simulink's core principles, interface, and practical applications. One of the central outcomes of the course is gaining proficiency in modelling dynamic systems using Simulink's intuitive block diagram environment. Participants learn to represent complex systems with ease, leveraging Simulink's extensive library of pre-built blocks and components. Moreover, the course equips participants with essential skills in simulating dynamic systems, allowing them to analyze system behaviour and performance under various conditions. By setting up simulations and running them within Simulink, participants gain valuable insights into system dynamics and response characteristics.

WHAT I LEARNT ?

- Completing the Simulink Onramp course has yielded significant outcomes, providing a solid foundation in Simulink and its practical applications.
- The course, participants have gained comprehensive knowledge of Simulink's interface, tools, and functionalities.
- Completing the Simulink Onramp course has empowered participants with the knowledge, skills, and confidence to leverage Simulink effectively for modelling and simulating dynamic systems.
- well-equipped to tackle complex problems and pursue advanced topics in Simulink with a strong foundation in place.

COURSE DURATION

2 HOURS

COURSE GRADE

100%

3.17 SIGNAL PROCESSING ONRAMP

DESCRIPTION

Completing the Signal Processing Onramp course is an essential step towards mastering signal processing techniques using MATLAB. Throughout the course, participants delve into fundamental concepts such as time-domain and frequency-domain analysis, filtering, convolution, and spectral analysis. They gain a comprehensive understanding of how signals are processed and analyzed across various domains, including audio, speech, image, and biomedical signal processing. Participants also acquire practical skills in MATLAB, learning how to implement signal processing algorithms and techniques using MATLAB's built-in functions and tools. They explore methods for filtering signals, performing Fourier analysis, and conducting digital signal processing (DSP), enabling them to manipulate and analyze signals effectively. Hands-on exercises and projects provide participants with opportunities to reinforce their learning and apply signal processing techniques to real-world problems. Through these activities, participants develop proficiency in visualizing signals and interpreting analysis results using MATLAB's plotting and visualization capabilities.

WHAT I LEARNT ?

- Participants gain a strong foundational understanding of signal processing concepts and techniques, including time-domain and frequency-domain analysis, filtering, convolution, and spectral analysis.
- Implementing signal processing algorithms and techniques using MATLAB's tools and functions. They learn how to manipulate and analyze signals effectively, perform filtering operations, and conduct spectral analysis.
- Hands-on exercises and projects, participants gain practical experience in using MATLAB for signal processing tasks.

COURSE DURATION

1.5 HOURS

COURSE GRADE

100%

3.18 SOLVING NONLINEAR EQUATIONS WITH MATLAB

DESCRIPTION

Completing the "Solving Nonlinear Equations with MATLAB" course equips participants with a comprehensive understanding of methods and techniques for solving nonlinear equations using MATLAB. Throughout the course, participants delve into various numerical methods, optimization techniques, and root-finding algorithms commonly employed in solving nonlinear equations. Participants gain proficiency in implementing these methods and algorithms using MATLAB's built-in functions and tools. They learn how to formulate nonlinear equations, apply appropriate numerical techniques, and interpret results effectively using MATLAB's programming environment. Hands-on exercises and projects provide participants with practical experience in solving a wide range of nonlinear equations encountered in engineering, science, finance, and other domains.

WHAT I LEARNT ?

- Participants become proficient in using a variety of numerical methods and algorithms for solving nonlinear equations, such as iterative methods, optimization techniques, and root-finding algorithms.
- Advanced MATLAB programming skills, learning how to implement and apply numerical methods to solve nonlinear equations efficiently.
- Participants acquire practical experience in solving a diverse range of nonlinear equation problems encountered in various fields, such as engineering, science, finance, and economics.

COURSE DURATION

3 HOURS

COURSE GRADE

100%

3.19 STATISTICS ONRAMP

DESCRIPTION

The "Statistics Onramp" course offers participants a comprehensive introduction to statistics concepts and their practical applications using MATLAB. Throughout the course, participants delve into fundamental statistical principles, methods, and techniques, gaining a solid foundation in statistical analysis and interpretation. Key topics covered in the course include descriptive statistics, probability distributions, hypothesis testing, confidence intervals, regression analysis, and ANOVA (analysis of variance). Participants learn how to use MATLAB's statistical functions and tools to perform various statistical analyses and visualize data effectively. Hands-on exercises and projects provide participants with practical experience in applying statistical methods to real-world datasets. Through these activities, participants develop proficiency in data analysis, interpretation, and decision-making, enhancing their problem-solving skills and critical thinking abilities.

WHAT I LEARNT ?

- Participants gain a strong foundational understanding of statistical concepts, including descriptive statistics, probability distributions, hypothesis testing, and regression analysis.
- Practical skills in using MATLAB for statistical analysis, learning how to perform various statistical tests, calculations, and visualizations efficiently.
- Interpreting data using statistical methods, enabling them to draw meaningful conclusions and make informed decisions based on data insights.

COURSE DURATION

1.5 HOURS

COURSE GRADE

100%



Course Completion Certificate

Durgadevi J

has successfully completed **100%** of the self-paced training course

MATLAB Onramp



DIRECTOR, TRAINING SERVICES

8 November 2023



Course Completion Certificate

Durgadevi J

has successfully completed **100%** of the self-paced training course

MATLAB Fundamentals



DIRECTOR, TRAINING SERVICES

12 November 2023



Course Completion Certificate

Durgadevi J

has successfully completed **100%** of the self-paced training course

Machine Learning Onramp

A handwritten signature in black ink, reading "Craig T. Hunter".

DIRECTOR, TRAINING SERVICES

15 November 2023



Course Completion Certificate

Durgadevi J

has successfully completed **100%** of the self-paced training course

Statistics Onramp

A handwritten signature in black ink, reading "Craig T. Hunter".

DIRECTOR, TRAINING SERVICES

15 November 2023



Course Completion Certificate

Durgadevi J

has successfully completed **100%** of the self-paced training course

App Building Onramp


DIRECTOR, TRAINING SERVICES

20 November 2023



Course Completion Certificate

Durgadevi J

has successfully completed **100%** of the self-paced training course

Object-Oriented Programming Onramp


DIRECTOR, TRAINING SERVICES

1 December 2023



Course Completion Certificate

Durgadevi J

has successfully completed **100%** of the self-paced training course

Computer Vision Onramp


DIRECTOR, TRAINING SERVICES

1 December 2023



Course Completion Certificate

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has successfully completed **100%** of the self-paced training course

Signal Processing with MATLAB


DIRECTOR, TRAINING SERVICES

12 March 2024



Course Completion Certificate

Durgadevi J

has successfully completed **100%** of the self-paced training course

Reinforcement Learning Onramp

A handwritten signature in black ink, appearing to read "Craig L. Santos".

DIRECTOR, TRAINING SERVICES

2 December 2023



Course Completion Certificate

Durgadevi J

has successfully completed **100%** of the self-paced training course

Machine Learning with MATLAB


DIRECTOR, TRAINING SERVICES

2 December 2023



Course Completion Certificate

Durgadevi J

has successfully completed **100%** of the self-paced training course
MATLAB for Data Processing and Visualization


DIRECTOR, TRAINING SERVICES

3 December 2023



Course Completion Certificate

Durgadevi J

has successfully completed **100%** of the self-paced training course
Image Processing with MATLAB


DIRECTOR, TRAINING SERVICES

5 March 2024



Course Completion Certificate

Durgadevi J

has successfully completed **100%** of the self-paced training course

Deep Learning with MATLAB


DIRECTOR, TRAINING SERVICES

3 December 2023



Course Completion Certificate

Durgadevi J

has successfully completed **100%** of the self-paced training course

Deep Learning Onramp


DIRECTOR, TRAINING SERVICES

3 December 2023



Course Completion Certificate

Durgadevi J

has successfully completed **100%** of the self-paced training course

MATLAB Programming Techniques


DIRECTOR, TRAINING SERVICES

22 February 2024



Course Completion Certificate

Durgadevi J

has successfully completed **100%** of the self-paced training course

Image Processing Onramp


DIRECTOR, TRAINING SERVICES

1 March 2024



Course Completion Certificate

Durgadevi J

has successfully completed **100%** of the self-paced training course

Solving Nonlinear Equations with MATLAB



Craig L. Santos

DIRECTOR, TRAINING SERVICES

25 March 2024



Course Completion Certificate

Durgadevi J

has successfully completed **100%** of the self-paced training course

Simulink Onramp


DIRECTOR, TRAINING SERVICES

26 March 2024



Course Completion Certificate

Durgadevi J

has successfully completed **100%** of the self-paced training course

Signal Processing Onramp


DIRECTOR, TRAINING SERVICES

5 March 2024



NPTEL Online Certification

(Funded by the MoE, Govt. of India)



This certificate is awarded to

DURGADEVI J

for successfully completing the course

Mathematical Modelling: Analysis and Applications

with a consolidated score of **56** %

Online Assignments	21.67/25	Proctored Exam	34.5/75
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Total number of candidates certified in this course: **36**

Prof. Kaushik Ghosh,
Professor (Chemistry)
Coordinator CEC

Jan-Feb 2024

(4 week course)

Prof. Ranjana Pathania,
Professor (BSBE)
Coordinator (NPTEL)



Indian Institute of Technology Roorkee



Roll No: NPTEL24MA32S653404071

To verify the certificate



No. of credits recommended: 1 or 2