

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
JAYASREE K (43739005)



DEPARTMENT OF BIOINFORMATICS AND DATA SCIENCE

SCHOOL OF BIO AND CHEMICAL ENGINEERING

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)

Accredited with Grade "A++" by NAAC

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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 **JAYASREE K (43739005)** who carried out the project entitled "**Mathematical Modelling: Analysis and Applications**" 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, **JAYASREE K** 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:

JAYASREE K

PLACE: CHENNAI

SIGNATURE OF THE CANDIDATE

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(JAYASREE K)

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1. NATIONAL PROGRAMME ON TECHNOLOGY ENHANCED LEARNING [NPTEL]

MATHEMATICAL MODELLING

INTRODUCTION TO NPTEL:

The National Programme on Technology Enhanced Learning (NPTEL) is an Indian e-learning platform for university-level science, technology, engineering, and mathematics (STEM) subjects. It is jointly developed by Indian Institutes of Technology (IITs) and Indian Institute of Science.[1] The initiative is funded by the central Ministry of Education.

- Largest online repository in the world of courses in engineering, basic sciences and selected humanities and management subjects
- YouTube channel for NPTEL – most subscribed educational channel, 1.3 billion views and 40+ lakhs subscribers
- More than 56000 hours of video content, transcribed and subtitled
- Most accessed library of peer-reviewed educational content in the world
- Translation of more than 12000 hrs of English transcripts in regional Indian languages

INTRODUCTION TO MATHEMATICAL MODELLING:

A dictionary meaning of a “model” is to represent something. Thus, modeling is a process or a way of representation. Now, what are we supposed to represent? The nature or behavior of the system and/or the activities involved in it! Again, what are the ways to represent? It may be done by a drawing or some verbal arguments or a physical structure or mathematical formulas. Thus, the mathematical modeling is a process of representation of the system with help of mathematical formulas and the mathematical model is the structure obtained.

Mathematical modeling has applications in almost every field of engineering and sciences. Whether it is

- To study the crime rate – Sociology or
-
- To construct a building – Engineering or
- To analyze the patterns in planets - Astrophysics, everywhere mathematical models help us.

In day-to-day life, you might have questioned your-self for

- How the current of electrons flow? – Ohm's and Kirchhoff's Laws.
- How tea leaves start dissolving in boiling water? – Fick's Law.
- Why the water come out from a tap in nice manner? – Navier Stoke's Equation.

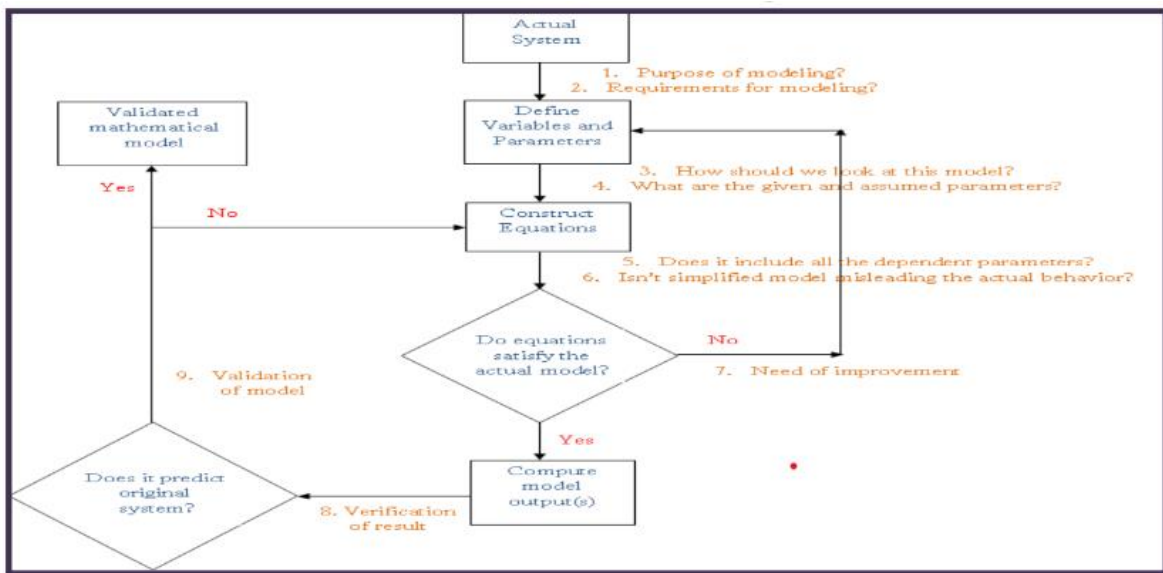


Figure 1: Mathematical Modelling Process

COURSE OUTCOME:

This course provides introduction of mathematical modeling and analysis in biological sciences. It is designed for students in both applied mathematics and bio-medical / biological sciences. The 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 SCOPE:

1. Physical Sciences: Mathematical models are extensively used in physics, chemistry, and biology to describe physical phenomena, such as motion, chemical reactions, and population dynamics.

2. Engineering: Engineers use mathematical models to design and optimize systems and processes, such as electrical circuits, mechanical structures, and transportation networks.

3. Economics and Finance: Mathematical models play a crucial role in economic forecasting, risk assessment, and portfolio optimization, helping businesses and policymakers make informed decisions.

4. Environmental Science: Mathematical models are used to study environmental processes, including climate change, pollution dispersion, and ecosystem dynamics, aiding in environmental policy development and management.

5. Social Sciences: Mathematical modeling is employed in sociology, psychology, and political science to understand social behavior, opinion dynamics, and decision-making processes.

6. Medicine and Healthcare: Mathematical models are used in epidemiology to study the spread of diseases, in pharmacokinetics to optimize drug dosing, and in medical imaging for diagnosis and treatment planning.

7. Computer Science: Mathematical models underpin algorithms and data structures used in computer science, including optimization algorithms, machine learning models, and cryptographic protocols.

8. Operations Research: Mathematical models are applied to optimize decision-making processes in various domains, such as logistics, supply chain management, and scheduling.

9. Energy and Environmental Engineering: Mathematical models are utilized in energy systems analysis, renewable energy integration, and environmental impact assessment.

10.Astronomy and Astrophysics: Mathematical models are essential for understanding celestial phenomena, such as planetary motion, stellar evolution, and cosmology.

COURSE LAYOUT:

- WEEK 1: Overview of mathematical modeling, 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.

DURATION:

4 Weeks

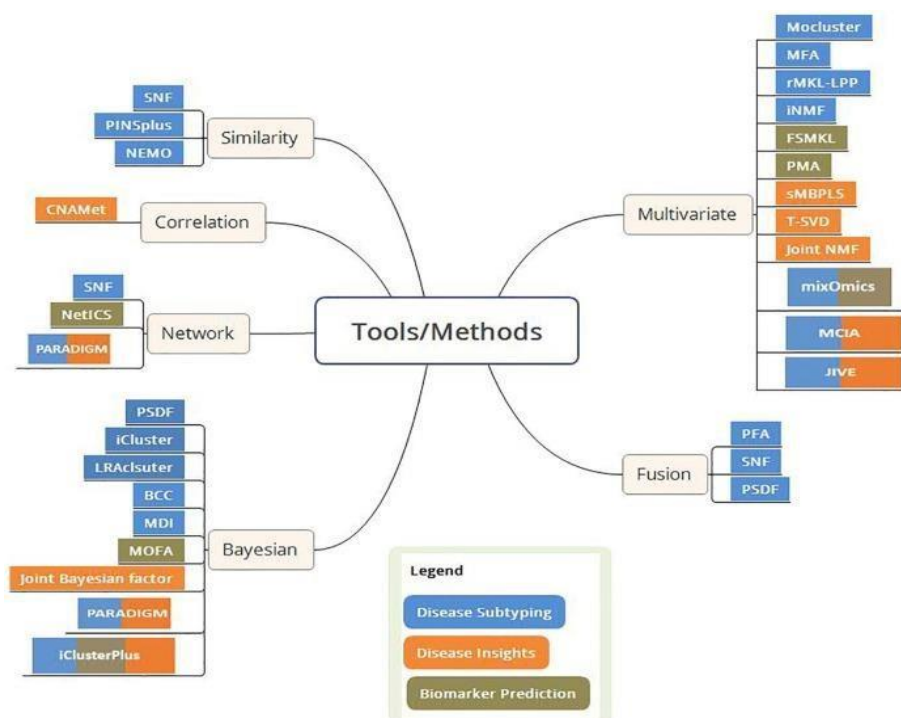
GRADE:

50%

2. MULTI OMICS DATA INTEGRATION AND ANALYSIS

INTEGRATING THE LAYERS OF BIOLOGY: MULTI-OMICS DATA ANALYSIS STRATEGIES

Methods for integrating Genomics, Transcriptomics and Proteomic data



An important area of research in systems biology is the integration of genomics, transcriptomics, and proteomic data methods to provide a more complete understanding of cellular functions and molecular interactions.

Understanding an organism's genetic makeup through genomics helps us understand differences in its DNA sequence, levels of gene expression, and regulatory elements that control transcriptional activity. Conversely, transcriptomics is concerned with characterizing the entire transcriptome and identifying changing patterns of gene

expression across different cell types, developmental stages, and environmental factors. Finally, proteomics elucidates the proteome, the entire set of proteins expressed in a cell or tissue, as well as their relationships, abundance levels, and post-translational modifications. Researchers can discover regulatory networks, understand the flow of genetic information from DNA to RNA to protein, and by integrating these multiomics datasets identify molecular markers linked to

physiological states, disease phenotypes, and therapeutic responses. Various statistical and computational techniques have been developed to combine proteome, transcriptomics, and genomics data; Each is designed to address a specific research objective, data type, and biological context. For example, co-expression analysis identifies genes or proteins with similar expression patterns in multiple omics datasets, revealing regulatory networks, functional modules, and putative biomechanisms. Gene co-expression networks were generated using weighted gene co-expression network analysis (WGCNA), which identifies highly interconnected gene modules linked to specific biological processes or clinical traits. Similarly, pathway enrichment analysis identifies dysregulated pathways, functional annotations, and potential therapeutic targets by combining omics data with known biological pathway information. Network-based techniques such as protein-protein interaction networks or regulatory networks integrate genomics, transcriptomics, and proteomic data to map molecular interactions, predict novel protein-protein interactions, and infer regulatory relationships between genes, transcription factors, and microRNAs. Support vector machines, random forests, and neural networks are some examples of machine learning algorithms. Distributed Stochastic Neighbor Embedding (t-SNE) are two-dimensional minimization techniques that facilitate visualization and interpretation of multi-omics datasets. They do this by transforming high-dimensional data into low-dimensional representations while maintaining important biological variability. Furthermore, resources for accessing, analyzing, and visualizing multi-omics data across different tissues, diseases, and experimental conditions are available through integrated omics platforms and databases such as the Human Protein Atlas (HPA), Genotype-Tissue Expression, etc. (GTEx) project, and Cancer Genome Atlas (TCGA). Despite these developments, problems with data heterogeneity, batch effects, missing values, and sample size limitations remain when integrating genomics, transcriptomics, and proteomic data. In addition, interpretation of integrative omics results requires careful consideration of biological context, functional validation, and integration. Other data methods such as metabolomics, epigenomics, and singlecell sequencing. Nevertheless, the integration of genomics, transcriptomics, and proteomic data holds enormous promise for improving our understanding of complex biological systems, unraveling disease mechanisms, and guiding precision clinical approaches tailored to the molecular profiles of individual patients. Through continued interdisciplinary collaboration, methodological innovation, and data sharing efforts,

integrative omics approaches will drive transformative discoveries in biology and medicine, ultimately improving human health and well-being.

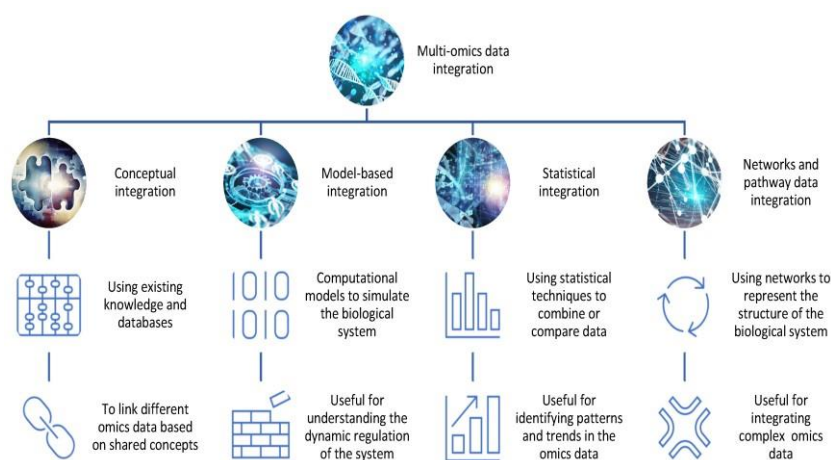
Statistical approaches for Multi - omics data integration and interpretation

Statistical methods for multi-omics data integration and interpretation are needed to fully realize the potential of omics technologies and gain a more complete understanding of complex biological systems. Multi-omics refers to the simultaneous measurement and analysis of multiple types of biological data, including proteomics, metabolomics, genomics, transcriptomics, and epigenomics, to provide a comprehensive understanding of cellular processes. The sheer volume of data collected, variations in data types, and sources of change make integrating and understanding these heterogeneous datasets difficult. Finding significant connections and interactions between different omics layers is a key objective of multi-omics integration, as it enables scientists to discover biological processes and unknown biomolecular networks. Statistical approaches are essential to this process as they provide a robust framework for data integration. Correlation analysis is a popular method for multi-omics integration that seeks to discover relationships between variables in different omics layers. Correlation-based techniques use metrics such as Pearson's correlation coefficient or Spearman's rank correlation coefficient to quantify the direction and intensity of associations between pairs of omics traits such as genes, proteins, or metabolites. By calculating correlations between omics datasets researchers can identify co-expressed genes, co-regulated pathways and potential biomolecular interactions. Correlation analysis may not fully capture more complex interactions, such as regulatory interactions or nonlinear connections. Advanced statistical techniques such as network-based algorithms for multi-omics integration have been developed to overcome these limitations. Based on co-occurrence or co-expression patterns across biological entities (nodes) and their connections (edges), network analysis creates graphical models. These networks can be visualized and analyzed to identify highly connected modules or clusters that correlate with biological processes or functional pathways. Weighted gene co-expression network analysis (WGCNA), for example, identifies hub genes, essential components of regulatory

networks, and classifies genes into modules based on how they express themselves across samples. To elucidate biological processes and interactions, proteomics and metabolomics data can be used to construct protein-protein interaction networks and metabolic networks, respectively. Principal component analysis (PCA) and related dimension reduction methods are another useful strategy for multi-omics integration. PCA preserves as much variation as possible when transforming high-dimensional omics data into a low-dimensional space. PCA can identify underlying patterns and structure in data by projecting it onto a small set of orthogonal components. By combining multiple omics datasets into a single analysis, multi-omics PCA enables researchers to identify similar or distinct patterns across different strata. Furthermore, correlations between omics datasets can be detected using supervised dimension reduction techniques such as canonical correlation analysis (CCA) and partial least squares (PLS) regression, which take into account model annotations or phenotypic effects. Furthermore, multi-omics data integration is increasing. Using machine learning algorithms including support vector machines (SVM), random forests and deep learning models. These techniques use large amounts of data and computing power to process multidimensional omics datasets for complex patterns and predictive models. Integrated classifiers can, for example, use information from multiple omics layers to predict clinical outcomes or disease subtypes, improving patient stratification and diagnostic accuracy. Deep learning frameworks can automatically create hierarchical representations of omics data, capturing complex interactions and interactions between traits. Examples of these designs are Convolutional Neural Networks (CNNs) and Deep Belief Networks (DBNs). In addition to these techniques, Bayesian approaches provide a probabilistic framework for prior knowledge integration and uncertainty modeling in multi-omics research. For example, Bayesian networks are acyclic graphs that enable the modeling of pathways and the inference of causal relationships between variables and the dependencies between them. Techniques for standardizing and normalizing data are essential to reduce batch effects and synchronize data across platforms. Furthermore, robust feature selection and dimensionality reduction techniques are essential for the analysis of highdimensional multi-omics datasets due to the curse of dimensionality. Furthermore, confounding variables including batch effects, sample heterogeneity, and technical artifacts must be taken into account for the results to be reliable and repeatable. Statistical methods for integrating and analyzing multi-omics data are, in summary,

essential to advance our understanding. Complex biological systems and causes of disease. Researchers can integrate omics information from genomics, transcriptomics, proteomics, metabolomics, and epigenomics to uncover hidden biological insights and potential therapeutic targets using a variety of statistical techniques. From dimensionality reduction techniques and machine learning algorithms to correlation analysis and network-based approaches.

Biomedical applications of integrated Multi - omics analysis



The use of integrated multi-omics analysis for biomedical purposes has transformed our understanding of complex biological systems and provided previously unheard insights into the

molecular pathways that underlie both health and disease. Multiomics approaches combine data from genomics, transcriptomics, epigenomics, proteomics, and other metabolomics to provide a comprehensive understanding of biological processes at the molecular level and elucidate the complex interactions between genes, proteins, metabolites, and other molecular entities. Omics methods. Discovery of important molecular drivers, biomarkers and therapeutic targets for diseases as diverse as cancer, cardiovascular disease, neurological disorders, infectious diseases and autoimmune diseases is facilitated by these integrative analyses. Integrative multi-omics analysis can help predict treatment response, guide treatment selection, patient stratification, and characterize tumor heterogeneity, clonal evolution, and genetic subtypes of cancer. Through the integration of gene mutations, gene expression profiles, epigenetic changes, and protein expression patterns, researchers can identify potential therapeutic targets, dysregulated signaling pathways, and actionable mutations. This allows the development of personalized treatment plans based on the molecular profiles of individual patients. In addition, multi-omics techniques shed light

on the dynamics of the tumor microenvironment, immune evasion mechanisms, and tumor-immune interactions. This knowledge informs the development of combination regimens and immunotherapies to enhance antitumor immunity and overcome past treatment resistance. Integrative multi-omics analysis in cardiovascular disorders helps identify new therapeutic targets for arrhythmias, heart failure and atherosclerosis, as well as elucidates disease mechanisms and biomarker development. By combining gene expression variations, proteomic profiles, metabolic changes, and genetic variants linked to cardiovascular pathophysiology, scientists can understand complex disease pathways, identify molecular markers of disease progression, and develop interventions designed to reduce adverse clinical outcomes. Furthermore, the use of multi-omics techniques facilitates the identification of molecular biomarkers for prognostication, risk assessment and early diagnosis. This allows immediate interventions to stop cardiovascular events and improve patient outcomes. Integrative multi-omics analysis sheds light on the molecular causes of neurodegeneration, neuroinflammation and synaptic dysfunction in neurological disorders. This opens new avenues for identifying biomarkers and developing disease-modifying therapies for multiple sclerosis, Parkinson's disease, Alzheimer's disease and other diseases. By integrating genomic, transcriptomic, proteomic, and metabolomic data from patient samples and disease models, researchers can identify diseasespecific molecular signatures, pathways, and therapeutic targets. This opens the door to precision medicine approaches customized to individual patients' molecular subtypes and disease states. Furthermore, multiomics analysis provides new insights into the etiology and pathophysiology of disease by elucidating geneenvironment interactions, epigenetic changes, and microbial contributions to neuronal health and disease. The development of vaccines, antimicrobial therapies, and diagnostic tests for infectious agents such as bacteria, viruses, fungi, and parasites is guided by host-pathogen interactions, immune responses, and potential microvirulence mechanisms through integrated multi-omics analysis. By integrating genomic, transcriptomic, proteomic, and metabolomic data from host cells and pathogens, researchers can identify molecular signatures of infection, drug resistance, and disease severity. This allows for the development of precise clinical approaches customized to the immune responses and pathogen profiles of individual patients. Multi-omics analysis also sheds light on the dynamics of microbial communities, the mechanisms underlying

antibiotic resistance, and the ways in which infections spread. All this knowledge aims to inform public health policies.

Future directions in Multi - omics data research and technologies

Future advances in multi-omics data science and technology have the potential to transform how we understand complex biological systems, fuel advances in precision medicine, and transform the delivery of health care. The exponential growth in omics data volume, diversity, and velocity has created a critical need for sophisticated computational and analytical techniques to draw meaningful conclusions from these rich datasets. Integration of multi-omics data, identification of biomarkers, and unparalleled accuracy of disease outcome predictions are all made possible by machine learning algorithms, deep learning models, and artificial intelligence approaches. Furthermore, by combining multi-omics data with other data modalities, including imaging, electronic health records, and environmental exposures, a more complete understanding of disease causes, progression, and response to treatment is possible. At the same time, the development of experimental tools such as spatial transcriptomics, single-cell sequencing, and multi-modal omics profiling will provide hitherto unattainable levels of granularity and resolution to describe tissue microenvironments, molecular interactions, and cellular heterogeneity. Personalized medicine techniques based on individual patients' molecular profiles are possible with these technologies, which can aid in drug selection, dose optimization, and treatment monitoring. Furthermore, the democratization of omics technologies and data sharing programs will enable academics to communicate globally, democratize access to omics data, and accelerate scientific discovery. However, there are challenges in standardizing omics data acquisition, processing, and analysis pipelines, ensuring data quality, and reproducibility and interoperability across surveys and platforms. Furthermore, ethical considerations, privacy concerns, and regulatory frameworks must be addressed to protect patient privacy, informed consent, and data security in the era of big data and precision medicine. Nevertheless, with continued interdisciplinary collaboration, methodological innovation, and global collaboration, multi-omics data research and technologies have the potential to open new frontiers in biology, medicine, and healthcare, ultimately improving human health and well-being.

JAYASREE. K

ORIGINALITY REPORT

10%

SIMILARITY INDEX

7%

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PUBLICATIONS

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STUDENT PAPERS

PRIMARY SOURCES

1	"Computational Methods and Data Analysis for Metabolomics", Springer Science and Business Media LLC, 2020 Publication	1%
2	www.frontiersin.org Internet Source	1%
3	Submitted to University of South Australia Student Paper	1%
4	Yuxin Zhao, Xiaobo Li, Changjun Zhou, Hao Pen, Zhonglong Zheng, Jun Chen, Weiping Ding. "A review of cancer data fusion methods based on deep learning", Information Fusion, 2024 Publication	1%
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13	Indhupriya Subramanian, Srikant Verma, Shiva Kumar, Abhay Jere, Krishanpal Anamika. "Multi-omics Data Integration, Interpretation, and Its Application", Bioinformatics and Biology Insights, 2020 Publication	<1 %
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Guangyan Zhou, Jianguo Xia. "Using OmicsNet for Network Integration and 3D Visualization", Current Protocols in Bioinformatics, 2018

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Zhengqing Wan, Haofeng Xiong, Xian Tan, Tong Su, Kun Xia, Danling Wang. "Integrative Multi-Omics Analysis Reveals Candidate Biomarkers for Oral Squamous Cell Carcinoma", Frontiers in Oncology, 2022

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3. MATLAB COURSES

Based on the MATLAB Certificate there are 19 Course I have completed:

Basic Courses

- ✓ MATLAB Onramp
- ✓ Simulink Onramp
- ✓ Signal Processing Onramp
- ✓ Image Processing Onramp
- ✓ Machine Learning Onramp
- ✓ Deep Learning Onramp
- ✓ Computer Vision Onramp

Advanced Courses

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

BASIC COURSES

3.1 MATLAB ONRAMP

DESCRIPTION:

The MATLAB Onramp is an interactive introductory tutorial provided by MathWorks, offering users a hands-on learning experience to get started with MATLAB, a widely used programming language and environment for technical computing. Through a series of self-paced modules, users are guided step-by-step to learn MATLAB's syntax, fundamental operations, and essential programming constructs. The Onramp covers key topics such as variables, arrays, loops, conditional statements, and functions, providing a solid foundation in MATLAB programming. MATLAB Onramp serves as an accessible entry point for individuals looking to acquire basic MATLAB skills for academic, research, or professional purposes.

OBJECTIVES

- Introduce users to the basic syntax, functions, and operations of MATLAB.
- Familiarize users with fundamental programming concepts such as variables, arrays, loops, and conditional statements.
- Enable users to create, edit, and run MATLAB code within a user-friendly online environment.
- Teach users how to visualize data, perform basic data analysis, and generate plots using MATLAB's plotting functions.

DURATION:

2 Hours

GRADE:

100%

3.2 SIMULINK ONRAMP

DESCRIPTION:

The Simulink Onramp is an interactive tutorial provided by MathWorks, tailored to introduce users to Simulink, a powerful graphical programming environment for modeling and simulating dynamic systems. Additionally, the Simulink Onramp covers advanced topics such as organizing models using subsystems and creating custom blocks to enhance model clarity and reusability. Ultimately, the Simulink Onramp provides users with the foundational knowledge and skills needed to start using Simulink effectively for a wide range of engineering and scientific applications, empowering them to accelerate their learning curve and apply Simulink to solve real-world problems.

OBJECTIVES:

- Understand the capabilities and applications of Simulink for modeling, simulating, and analysing dynamic systems in engineering and science fields.
- Gain proficiency in building and simulating models using Simulink, including connecting blocks, setting block parameters, and running simulations to analyze system behavior.
- Develop skills in organizing models using subsystems and creating custom blocks to encapsulate functionality and improve model clarity and reusability.
- Acquire problem-solving and critical thinking skills by completing hands-on exercises and practical examples that demonstrate the application of Simulink in real-life scenarios.

DURATION:

2 Hours

GRADE:

100%

3.3 SIGNAL PROCESSING ONRAMP

DESCRIPTION:

The Signal Processing Onramp is an interactive tutorial provided by MathWorks, designed to introduce users to the fundamentals of signal processing using MATLAB and Signal Processing Toolbox. The Signal Processing Onramp also provides guidance on visualizing signals, interpreting spectral content, and applying signal processing techniques to real-world applications in areas such as audio processing, image processing, and biomedical signal analysis.

OBJECTIVES:

- Understand the basic concepts and principles of signal processing, including time-domain and frequency-domain representations of signals, sampling, filtering.
- Learn how to analyze and manipulate signals using MATLAB and Signal Processing Toolbox, including techniques for signal visualization, filtering, spectral analysis, and time-frequency analysis.
- Gain proficiency in using MATLAB and Signal Processing Toolbox functions and commands to perform common signal processing tasks, such as signal denoising, feature extraction, and system identification.
- Develop problem-solving skills and critical thinking by completing hands-on exercises and practical examples that demonstrate the application of signal processing techniques to real-world scenarios, like image processing.

DURATION:

1.5 Hours

GRADE:

100%

3.4 IMAGE PROCESSING ONRAMP

DESCRIPTION:

The Image Processing Onramp is an interactive learning resource provided by MathWorks, aimed at introducing users to the fundamentals of image processing using MATLAB and Image Processing Toolbox. Image Processing Onramp, users acquire the foundational knowledge and skills needed to start using MATLAB and Image Processing Toolbox effectively for image processing tasks, empowering them to tackle a wide range of image analysis challenges in various engineering and scientific domains.

OBJECTIVES:

- Understand the basic concepts and principles of digital image processing, including image representation, enhancement, segmentation, and analysis.
- Learn how to perform common image processing tasks using MATLAB, such as image filtering, edge detection, morphological operations, and feature extraction.
- Gain proficiency in using MATLAB functions and commands for image manipulation and analysis, including image visualization, processing, and measurement.
- Learn about advanced image processing techniques, such as image restoration, image compression, and image segmentation, and how these techniques are used in various applications, including medical imaging.

DURATION:

2 Hours

GRADE:

100%

3.5 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). Teaching techniques for data cleaning, preprocessing, and feature engineering to prepare data for machine learning models.

OBJECTIVES:

- Provide participants with a solid understanding of fundamental machine learning concepts, terminology, and methodologies.
- Introduce participants to various machine learning algorithms, including their strengths, weaknesses, and practical applications.
- Teach techniques for data preprocessing, cleaning, and feature engineering to prepare data for use in machine learning models.
- Offering hands-on experience through coding exercises or projects to apply machine learning concepts and algorithms to real-world problems using popular libraries like TensorFlow, Scikit-learn, or PyTorch. Discussing ethical implications, biases, and fairness concerns in machine learning applications.

DURATION:

2 Hours

GRADE:

100%

3.6 DEEP LEARNING ONRAMP

DESCRIPTION:

Deep learning models are based on neural network architectures. Inspired by the human brain, a neural network consists of interconnected nodes or neurons in a layered structure that relate the inputs to the desired outputs. The neurons between the input and output layers of a neural network are referred to as hidden layers. The term “deep” usually refers to the number of hidden layers in the neural network. Deep learning models can have hundreds or even thousands of hidden layers.

OBJECTIVES:

- Introduce participants to the core principles of deep learning, including neural network architecture, activation functions, loss functions, and optimization algorithms.
- Familiarize participants with various types of neural network architectures such as FNN, CNN, RNN, and GAN.
- Teach techniques for training deep learning models, including strategies for initializing model parameters, choosing appropriate loss functions, optimizing hyperparameters, and preventing overfitting.
- Provide opportunities for participants to gain practical experience by implementing deep learning models using popular deep learning frameworks such as TensorFlow or PyTorch. This may involve working on coding exercises, projects, or real-world datasets to apply deep learning concepts in practice.

DURATION:

7 Hours

GRADE:

100%

3.7 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. 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. 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 advanced computer vision algorithms.

OBJECTIVES:

- 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.
- Introduce participants to fundamental concepts in computer vision, including image representation, feature extraction, image classification, object detection, image segmentation, and image recognition.

DURATION:

2 Hours

GRADE:

100%

ADVANCED COURSES

3.8 MATLAB FUNDAMENTALS

DESCRIPTION:

"MATLAB fundamentals" refers to the foundational principles and concepts of MATLAB, a high-level programming language and interactive environment developed by MathWorks. These fundamentals encompass the essential knowledge required to understand and use MATLAB effectively for numerical computation, data analysis, visualization, and application development.

OBJECTIVES:

- Learn the basic syntax and programming constructs of MATLAB, including variables, arrays, and control flow statements.
- Understand how to perform mathematical operations, manipulate data structures, and work with matrices and vectors.
- Develop problem-solving skills and computational thinking by solving practical exercises and real-world problems using MATLAB.
- Acquire the foundational knowledge needed to explore more advanced topics in MATLAB, such as image processing, machine learning, and simulation.

DURATION:

16.5 Hours

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. The course covers a range of data analysis techniques available in MATLAB, including descriptive statistics, hypothesis testing, regression analysis, and clustering.

OBJECTIVES:

This helps us to learn how to create insightful visualizations of their data using MATLAB's plotting functions, including 2D and 3D plots, histograms, scatter plots.

- 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.

DURATION:

8 Hours

GRADE:

100%

3.10 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 like 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.

OBJECTIVES:

- Gaining a solid understanding of the MATLAB programming language, its syntax, and its various features.
- This course helps 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, pre allocation, and parallel computing.

DURATION:

16 Hours

GRADE:

100%

3.11 SOLVING NON-LINEAR EQUATIONS

DESCRIPTION:

In MATLAB, solving nonlinear equations involves finding the values of unknown variables that satisfy a set of equations that cannot be expressed as simple linear relationships. First, you define the equations using symbolic variables or anonymous functions. Then, convert these equations into MATLAB functions. Next, provide an initial guess for the variables involved. MATLAB provides various built-in functions for solving nonlinear equations, such as `'fsolve'`, `'fminunc'`, and `'lsqnonlin'`. Once you have the solution, you can display it and visualize it if needed using MATLAB's plotting capabilities.

OBJECTIVES:

- Learn how to accurately formulate nonlinear equations from real-world problems and express them in a format suitable for MATLAB computations.
- Understand different methods available in MATLAB for solving nonlinear equations and learn to select the most appropriate method based on problem characteristics, such as equation complexity, dimensionality, and constraints.
- Learn techniques for verifying the correctness and accuracy of the obtained solutions, including solution visualization and comparison with numerical benchmarks.
- Understand how to integrate optimization techniques into the solution process for nonlinear equations when dealing with optimization problems.

DURATION:

3 Hours

GRADE:

100%

3.12 SIGNAL PROCESSING WITH MATLAB

DESCRIPTION:

Signal processing with MATLAB involves the comprehensive analysis, manipulation, and interpretation of signals across various domains such as audio, image, and biomedical data. Additionally, it supports signal transformation between time and frequency domains, enabling users to perform Fourier analysis, wavelet transform, and other domain transformations. MATLAB's flexibility extends to signal simulation, modeling, and integration with other toolboxes for comprehensive solutions across domains like communications, image processing, and control systems.

OBJECTIVES:

- Acquire skills in visualizing signals using MATLAB's plotting functions, including time-domain waveforms, frequency-domain spectra, and spectrograms.
- Understand how to transform signals between different domains, such as time-domain to frequency-domain transformations using Fourier and wavelet transforms.
- Explore advanced signal processing techniques supported by MATLAB, including adaptive signal processing, time-frequency analysis, and blind source separation.
- Learn how to integrate signal processing with other domains such as communications, image processing, and biomedical engineering using MATLAB's integrated toolboxes.

DURATION:

7.5 Hours

GRADE:

100%

3.13 MACHINE LEARNING WITH MATLAB

DESCRIPTION:

Machine learning teaches computers to do what comes naturally to humans: learn from experience. Machine learning algorithms use computational methods to “learn” information directly from data without relying on a predetermined equation as a model. The algorithms adaptively improve their performance as the number of samples available for learning increases. Machine learning uses two types of techniques: supervised and unsupervised learning.

OBJECTIVES:

- Develop a solid understanding of fundamental machine learning concepts, including supervised and unsupervised learning, and reinforcement learning.
- Gain proficiency in using MATLAB's built-in machine learning functions, toolboxes, and libraries for model development, training, and evaluation.
- Learn how to implement and evaluate machine learning models using MATLAB, including techniques for data preprocessing, model selection, and performance evaluation.
- Acquire expertise in deep learning techniques, including convolutional neural networks (CNNs) and recurrent neural networks (RNNs), and learn how to build and train deep learning models using MATLAB.

DURATION:

12 hours

GRADE:

100%

3.14 IMAGE PROCESSING WITH MATLAB

DESCRIPTION:

Image processing with MATLAB involves utilizing MATLAB's comprehensive suite of functions and tools to analyze, manipulate, and enhance digital images. Users can perform tasks such as image acquisition, preprocessing, filtering, feature extraction, and analysis. MATLAB provides a wide range of algorithms and techniques for tasks like noise reduction, edge detection, object recognition, and image segmentation. Additionally, MATLAB offers powerful visualization capabilities for displaying processed images and results.

OBJECTIVES:

- Learn to acquire and preprocess images using MATLAB's functions and tools. This involves techniques such as image enhancement, noise reduction, and image registration to prepare images for further analysis.
- Understand and apply various image filtering and restoration techniques available in MATLAB, including spatial domain filters and frequency domain filters to enhance image quality and remove artifacts.
- Gain proficiency in techniques such as edge detection, texture analysis, object detection, and image segmentation to identify regions of interest within images.
- Learn how to visualize and present image processing results effectively using MATLAB's plotting and visualization functions.

DURATION:

11 Hours

GRADE:

100%

3.15 DEEP LEARNING WITH MATLAB

DESCRIPTION:

Deep learning models are based on neural network architectures. Inspired by the human brain, a neural network consists of interconnected nodes or neurons in a layered structure that relate the inputs to the desired outputs. The neurons between the input and output layers of a neural network are referred to as hidden layers. The term “deep” usually refers to the number of hidden layers in the neural network. Deep learning models can have hundreds or even thousands of hidden layers. With "Deep Learning with MATLAB," users can leverage a vast array of built-in algorithms and tools, including (CNNs), (RNNs), and (GANs).

OBJECTIVES:

- Gain a foundational understanding of deep learning concepts, including neural network architectures, activation functions, loss functions, and optimization algorithms.
- Develop proficiency in using MATLAB's deep learning functions, toolboxes, and libraries for building, training, and evaluating deep learning models.
- Learn how to implement and train deep learning models using MATLAB, including techniques for data preprocessing, model selection.
- Apply deep learning techniques to solve real-world problems in various domains, such as image classification, object detection, natural language processing, and time series analysis.

DURATION:

8 Hours

GRADE:

100%

3.16 OBJECT-ORIENTED PROGRAMMING ONRAMP

DESCRIPTION:

The Object-Oriented Programming (OOP) Onramp is a structured learning program aimed at introducing participants to the principles and practices of object-oriented programming using a specific language or framework, such as Python, Java, or C++. They learn how to design and implement object-oriented solutions to real-world problems, gaining hands-on experience through coding exercises, projects, and interactive tutorials. The onramp emphasizes best practices in software design, including modularization, code reusability, and maintainability. By the end of the onramp, participants are equipped with the foundational knowledge and skills necessary to apply object-oriented programming principles effectively in their programming projects and to continue their learning journey in software development.

OBJECTIVES:

- Learn fundamental concepts of object-oriented programming, including classes, objects, inheritance, and polymorphism.
- Gain proficiency in designing and implementing object-oriented solutions to real-world problems.
- Understand best practices in software design, emphasizing modularity, reusability, and maintainability.
- Apply learned skills through coding exercises and projects to build a strong foundation in object-oriented programming.

DURATION:

2 Hours

GRADE:

100%

3.17 APP BUILDING ONRAMP

DESCRIPTION:

The App Building Onramp is a structured learning program designed to equip participants with the skills and knowledge needed to develop mobile or web applications. Throughout the onramp, participants learn key concepts and tools related to app development, such as programming languages (e.g., Java, Swift), development frameworks (e.g., Android Studio, Xcode), user interface design, and application deployment. They engage in hands-on activities, tutorials, and projects to apply their learning and build functional applications from scratch. The onramp covers various aspects of app development, including frontend and backend development, user experience (UX) design, data management, and application testing.

OBJECTIVES:

- Learn fundamental concepts of app development, including programming languages, frameworks, and design principles.
- Gain hands-on experience in building mobile or web applications from scratch through guided projects.
- Understand the process of app deployment, including testing, debugging, and publishing to app stores or online platforms.
- Develop proficiency in frontend and backend development, user interface design, and application functionality to create functional and user-friendly apps.

DURATION:

1 Hour

GRADE:

100%

3.18 REINFORCEMENT LEARNING ONRAMP

DESCRIPTION:

The Reinforcement Learning Onramp is a structured learning program designed to introduce participants to the principles and techniques of reinforcement learning (RL). Throughout the onramp, participants delve into fundamental RL concepts such as Markov decision processes (MDPs), policy iteration, value iteration, and Q-learning. They gain practical experience through hands-on coding exercises, simulations, and projects using programming languages such as Python and frameworks like TensorFlow or PyTorch. The onramp covers a range of RL applications, including game playing, robotics, finance, and autonomous systems. By the end of the onramp, participants are equipped with the foundational knowledge and skills necessary to apply reinforcement learning algorithms effectively in various real-world scenarios.

OBJECTIVES:

- Understand fundamental concepts of reinforcement learning, such as Markov decision processes and value functions.
- Gain proficiency in implementing key reinforcement learning algorithms like Q-learning and deep Q-networks.
- Acquire hands-on experience through coding exercises to solve simulated and real-world problems.
- Explore the application of reinforcement learning techniques across various domains such as gaming, robotics, and finance.

DURATION:

2.5 Hours

GRADE:

100%

3.19 STATISTICS ONRAMP

DESCRIPTION:

The Statistics Onramp is a structured learning program designed to introduce participants to fundamental concepts and techniques in statistics. Throughout the onramp, participants engage in guided modules covering topics such as descriptive statistics, probability distributions, hypothesis testing, regression analysis, and data visualization. Hands-on exercises, interactive tutorials, and real-world case studies provide practical experience in applying statistical methods to analyze and interpret data. Participants also learn how to use statistical software such as R or Python with libraries like NumPy, SciPy, or pandas to perform statistical analysis efficiently.

OBJECTIVES:

- Develop a solid understanding of fundamental statistical concepts, including measures of central tendency, variability, probability, and hypothesis testing.
- Gain proficiency in applying statistical methods and techniques to analyze data, including descriptive statistics, inferential statistics, regression analysis, and hypothesis testing.
- Learn how to interpret statistical results and effectively communicate findings through data visualization techniques such as histograms, scatter plots, and box plots.
- Acquire hands-on experience through practical exercises and projects, enabling the application of statistical methods to real-world problems.

DURATION:

1.5 Hours

GRADE:

100%



NPTEL Online Certification

(Funded by the MoE, Govt. of India)



This certificate is awarded to

JAYASREE K

for successfully completing the course

Mathematical Modelling: Analysis and Applications

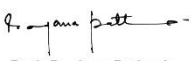
with a consolidated score of **50** %

Online Assignments	18.33/25	Proctored Exam	31.5/75
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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: NPTEL24MA32S644105344

To verify the certificate



No. of credits recommended: 1 or 2



Course Completion Certificate

Jayasree K

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

MATLAB Onramp


DIRECTOR, TRAINING SERVICES

12 November 2023



Course Completion Certificate

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Simulink Onramp


DIRECTOR, TRAINING SERVICES

27 March 2024



Course Completion Certificate

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Signal Processing Onramp


DIRECTOR, TRAINING SERVICES

7 March 2024



Course Completion Certificate

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Image Processing Onramp


DIRECTOR, TRAINING SERVICES

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Machine Learning Onramp


DIRECTOR, TRAINING SERVICES

19 December 2023



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Deep Learning Onramp


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Computer Vision Onramp

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

DIRECTOR, TRAINING SERVICES

19 December 2023



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MATLAB Fundamentals

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

DIRECTOR, TRAINING SERVICES

12 November 2023



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MATLAB for Data Processing and Visualization


DIRECTOR, TRAINING SERVICES

19 December 2023



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MATLAB Programming Techniques


DIRECTOR, TRAINING SERVICES

22 February 2024



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Solving Nonlinear Equations with MATLAB


DIRECTOR, TRAINING SERVICES

4 March 2024



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Signal Processing with MATLAB


DIRECTOR, TRAINING SERVICES

7 March 2024



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Machine Learning with MATLAB


DIRECTOR, TRAINING SERVICES

19 December 2023



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Image Processing with MATLAB


DIRECTOR, TRAINING SERVICES

3 March 2024



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Deep Learning with MATLAB

A handwritten signature in black ink, reading "Craig L. Santos".

DIRECTOR, TRAINING SERVICES

3 March 2024



Course Completion Certificate

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Object-Oriented Programming Onramp

A handwritten signature in black ink, reading "Craig L. Santos".

DIRECTOR, TRAINING SERVICES

1 December 2023



Course Completion Certificate

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App Building Onramp


DIRECTOR, TRAINING SERVICES

27 March 2024



Course Completion Certificate

Jayasree K

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

Reinforcement Learning Onramp


DIRECTOR, TRAINING SERVICES

3 February 2024



Course Completion Certificate

Jayasree K

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

Statistics Onramp



DIRECTOR, TRAINING SERVICES

29 February 2024