INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Centre for Artificial Intelligence and Data Science

1. **Subject Code:** AID-501 **Course Title**: Essential Mathematics for AI
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Autumn **7. Subject Area:** PCC
8. **Pre-requisite:** Nil
9. **Objective:** To introduce students to the various Mathematical concepts to be used in ML and AI
10. **Details of the Course**

S.No.	Contents	Contact hours
1.	**Basics of Linear Algebra:** System of Linear Equations; Vector space and sub-spaces (definition, examples and concepts of basis); Linear mappings; Matrices; Eigenvalues and Eigenvectors Norms; Inner Product; Orthogonally; Spectral Decomposition; Singular value Decomposition; Low-rank Approximation; Projection; Principal Component Analysis and Generative Models	10
2.	**Gradient Calculus:** Differentiation of univariate functions; partial derivatives and gradients; gradients of vector valued functions and matrices; Backpropagation and automatic differentiation; Linearization and Multivariate Taylor Series	6
3.	**Optimization:** Notion of maxima and minima; Optimization using gradient descent; Constrained Optimization techniques; Convex optimization Algorithms	8
4.	**Probability and Statistics**: Basic concepts of probability: conditional probability, Bayes' theorem, random variables, moments, moment generating functions, some useful distributions, Joint distribution, conditional distribution, transformations of random variables, covariance, correlation, random sample, statistics, sampling distributions, point estimation, MAP, MLE	14
5.	**Information Theory:** Entropy, cross-entropy, KL divergence, mutual information;	4
Total		**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication/Reprint
1	M. P. Deisenroth, A. A. Faisal, C. S. Ong, Mathematics for Machine Learning, Cambridge University Press (1^{st} edition)	2020
2	S. Axler, Linear Algebra Done Right. Springer International Publishing (3^{rd} edition)	2015
3	J. Nocedal and S. J. Wright, Numerical Optimization. New York: Springer Science+Business Media	2006
4	E. Kreyszig, Advanced Engineering Mathematics, John Wiley and Sons, Inc., U.K. (10^{th} Edition)	2015
5	R. A. Johnson, I. Miller, and J. E.Freund, "Miller & Freund's Probability and Statistics for Engineers", Prentice Hall PTR, (8^{th} edition)	2011

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Centre for Artificial Intelligence and Data Science

1. **Subject Code:** AID-503 **Course Title**: Computer Architecture for AI
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Autumn **7. Subject Area:** PCC
8. **Pre-requisite:** Nil
9. **Objective:** To learn the design of hardware architectures and accelerators for deep-learning/artificial-intelligence. This course is at the intersection of deep-learning and computer-architecture/embedded-system/VLSI.
10. **Details of the Course:**

S.No.	Contents	Contact Hours
1.	**Background topics:** Approximate computing and storage, Roofline Model, Cache tiling (blocking), GPU architecture, CUDA programming, understanding GPU memory hierarchy, FPGA architecture, Matrix multiplication using systolic array	8
2.	**Convolutional strategies:** Direct, FFT-based, Winograd-based and Matrix-multiplication based.	3
3.	**Deep learning on various hardware platforms:** Deep learning on FPGAs and case study of Microsoft's Brainwave, Deep learning on Embedded System (especially NVIDIA's Jetson Platform), Deep learning on Edge Devices (smartphones), Deep learning on an ASIC (especially Google's Tensor Processing Unit.), Deep-learning on CPUs and manycore processor (e.g., Xeon Phi), Memristor-based processing-in-memory accelerators for deep-learning.	15
4	**Memory-efficiency and reliability of DNN accelerators:** Model-size aware Pruning of DNNs, Hardware architecture-aware pruning of DNNs, Understanding soft-errors. Understanding reliability of deep learning algorithms and accelerators	6
5	**Memory-related tradeoffs in DNN accelerators:** Comparison of memory technologies (SRAM, DRAM, eDRAM, STT-RAM, PCM, Flash) and their suitability for designing memory-elements in DNN accelerator, Neural branch predictors and their applications	4
6	**Autonomous driving and DNN training:** Hardware/system-challenges in autonomous driving, Distributed training of DNNs and addressing memory challenges in DNN training	6
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication/Reprint
1.	Hennessy, J. L. ,& Patterson, D. A., **Computer Architecture: A quantitative approach** (Sixth Edition), Elsevier https://www.google.co.in/books/edition/Computer_Architecture/cM8mDwAAQBAJ	2017
2.	Brandon Reagen, Robert Adolf, Paul Whatmough, Gu-Yeon Wei, and David Brooks **Deep Learning for Computer Architects** Synthesis Lectures on Computer Architecture, August 2017, Vol. 12, No. 4, Pages 1-123 (https://doi.org/10.2200/S00783ED1V01Y201706CAC041)	2017
3	Tor M. Aamodt, Wilson Wai Lun Fung, and Timothy G. Rogers **General- Purpose Graphics Processor Architectures**, Synthesis Lectures on Computer Architecture, May 2018, Vol. 13, No. 2 , Pages 1-140 (https://doi.org/10.2200/S00848ED1V01Y201804CAC044)	2018
4	Goodfellow, I., Bengio, Y., Courville, A., & Bengio, Y. (2016). **Deeplearning (Vol. 1, No. 2)**. Cambridge: MIT press.	2016

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Center for Artificial Intelligence and Data Science

1. **Subject Code:** AID-505 **Course Title**: Machine Learning
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Autumn **7. Subject Area:** PCC
8. **Pre-requisite:** Nil
9. **Objective:** To provide an understanding of the theoretical concepts of machine learning and prepare students for research or industry application of machine learning techniques.

10. **Details of the Course**

S.No.	Contents	Contact hours
1.	**Introduction:** Well-posed learning problems, examples of machine learning applications, model selection and generalization, concept learning, inductive learning hypothesis, inductive bias. Information theory: entropy, mutual information, KL divergence	4
2.	**Performance Optimization:** Directional Derivatives, Minima, Necessary Conditions for Optimality, Convex function, Gradient Descent, Stable learning rates, Newtons Method, Conjugate gradient method, The Levenberg-Marquardt algorithm.	4
3.	**Linear Classification:** Linear classifier, Logistic Regression, Decision Boundary, Cost Function Optimization, Multi-class Classification, Bias and Variance, L1 and L2 Regularization, feature reduction, Principal Component Analysis, Singular Value Decomposition	4
4.	**Artificial Neural Networks:** Perceptron, Linear Networks, Multi-layer Networks, Forward propagation, Backward propagation, Alternative activation functions, variations on backpropagation, Deep neural networks.	5
5.	**Decision tree learning:** Decision tree representation, appropriate problems for decision tree learning, hypothesis space search in decision tree learning, inductive bias in tree learning, avoiding overfitting the data, alternative measures for selecting attribute values, ensemble methods, bagging, boosting, random forest	5
6.	**Support Vector Machines:** Computational learning theory, probably approximately correct (PAC) learning, sample complexity and VC dimension, linear SVM, soft margin SVM, kernel functions, nonlinear SVM, Multiclass classification using SVM, Support vector regression.	5
7.	**Instance based learning:** K-nearest neighbor learning, distance weighted neighbor learning, locally weighted regression, adaptive nearest neighbor methods, The Concept of Unsupervised Learning, Competition networks, K-means clustering algorithm.	3

8.	**Bayesian Learning:** Bayes theorem, maximum likelihood and least squared error hypotheses, Naive Bayes classifier, Bayesian belief networks, gradient ascent training of Bayesian networks, learning the structure of Bayesian networks, the EM algorithm, mixture of models, Markov models, hidden Markov models.	7
9.	**Reinforcement learning:** the learning task, Q learning, convergence, temporal difference learning, nondeterministic rewards and actions, generalization, relationship to dynamic programming.	5
Total		**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication /Reprint
1.	T. Mitchell, Machine Learning, McGraw Hill	1997
2.	Christopher Bishop, Pattern Recognition and Machine Learning, Springer	2006
3.	K. Murphy. Machine Learning: A probabilistic perspective, MIT Press	2012
4.	Hastie, Tibshirani, Friedman, Elements of statistical learning, Springer	2011
5.	I. Goodfellow, Y. Bengio and A. Courville. Deep Learning. MIT Press	2016
6.	Richard S. Sutton and Andrew G. Barto, Reinforcement Learning: AnIntroduction, MIT Press	2018

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Centre for Artificial Intelligence and Data Science

1. **Subject Code:** AID-507 **Course Title**: Advanced Data Structures and Algorithms
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Autumn **7. Subject Area:** PCC
8. **Pre-requisite:** Nil
9. **Objective:** To introduce advanced concepts in data structures and algorithms.

10. **Details of the Course**

S.No.	Contents	Contact hours
1.	**Data Structures:** Priority queues and heaps, dictionaries, hash tables, binary search trees, interval trees	8
2.	**Basic Algorithms:** Asymptotic notation, recursion, divide-and-conquer paradigm, greedy strategy, dynamic programming, graph algorithms, complexity classes P, NP, NP-hard, NP-complete.	8
3.	**Approximation Algorithms:** Performance ratio, vertex cover problem, travelling salesman problem, set covering problem, subset sum problem.	8
4.	**Randomized Algorithms:** Tools and techniques. Applications.	8
5.	**Multithreaded Algorithms:** Dynamic multithreaded programming, multithreaded matrix multiplication, multithreaded merge sort.	10
	Total	**42**

11. **Suggested Books:**

S.No.	Name of Authors/Book/Publisher	Year of Publication/ Reprint
1.	Wirth, N., “Algorithms and Data Structures”, Prentice-Hall of India.	2017
2.	Motwani and Raghavan, Randomized Algorithms. Cambridge University Press.	2014
3.	Brad Miller and David Ranum, Luther College, “Problem Solving with Algorithms and Data Structures Using Python,” Franklin, Beedle & Associates	2013
4.	Cormen T, Introduction to Algorithms, MIT Press, 3rd Edition.	2009

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Centre for Artificial Intelligence and Data Science

1. **Subject Code:** AID-509 **Course Title**: Programming for AI
2. **Contact Hours:** **L:** 0 **T:** 0 **P:** 4
3. **Examination Duration (Hrs.):** **Theory:** 0 **Practical:** 2
4. **Relative Weightage:** **CWS:** 0 **PRS:** 50 **MTE:** 0 **ETE:** 0 **PRE:** 50
5. **Credits:** 2 **6. Semester:** Autumn **7. Subject Area:** PCC
8. **Pre-requisite:** Nil
9. **Objective:** This course's objective is to provide hands-on experience on the various programming components for Artificial Intelligence.

10. **Details of the Course:**

S.No.	Contents	Contact hours
1.	Python: Basics, Numpy, Pandas, and Matplotlib	16
2.	Scikit-Learn and NLTK	12
3.	TensorFlow and Keras	12
4.	TensorFlow Lite: Deploy machine learning systems on IoT device (Arduino Platform and Raspberry Pi based devices) (C/C++, Python)	16
	Total	**56**

11. **Suggested Books:**

S.No.	Name of Authors/Book/Publisher	Year of Publication/ Reprint
1	Jake VanderPlas "Python Data Science Handbook," First Edition, O'Reilly Media,Inc.	2016
2	Wes McKinney "Python for Data Analysis: Data Wrangling with Pandas, NumPy, and IPython," Second Edition, O'Reilly Media, Inc.	2017
3	Pramod Singh and Avinash Manure "Learn TensorFlow 2.0: Implement Machine Learning and Deep Learning Models with Python," First Edition, Apress	2020
4	Aurélien Géron "Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow," Second Edition, O'Reilly Media, Inc.	2019
5	J. M. Hughes "Arduino: A Technical Reference: A Handbook for Technicians, Engineers, and Maker," First Edition, O'Reilly Media, Inc.	2016
6	Derek Molloy "Exploring Raspberry Pi: Interfacing to the Real World with Embedded Linux," First Edition, Wiley	2016

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Centre for Artificial Intelligence and Data Science

1. **Subject Code:** AID-551 **Course Title**: Convex Optimization in Machine Learning
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Both **7. Subject Area:** PEC
8. **Pre-requisite:** NIL
9. **Objective:** To introduce convex optimization algorithms to be used in various machine learning tools.
10. **Details of the Course**

S. No.	Contents	Contact hours
1.	**Introduction:** significance of optimization methods in machine learning, a brief review of the fundamentals of optimization, Convex sets and convex functions, Problems in Convex Optimization (linear/quadratic/Semi-definite programming), Strong and weak duality, rates of convergence	8
2.	**Optimization models**: Types of optimization models arising in different areas of ML, large scale optimization	6
3.	**First order optimization methods:** Gradient descent, stochastic gradient descent, NAG, Adam, ADMM, Frank and Wolfe, SVRG, AdaGrad, Implementation of these algorithms and their advantages and disadvantages	8
4.	**Second and higher order optimization methods:** Conjugate gradient, Newton's method, Quasi newton method, stochastic quasi Newton method, Hessian free method, Natural Gradient Method, Implementation of these algorithms and their advantages and disadvantages.	8
5.	**Optimization Solvers and Toolboxes:** CVX (MATLAB), CVXPY (Python), CVXOPT (Python)	6
6.	**Case Studies:** Recent developments and advanced optimization algorithms	6
	Total	**42**

11. **Suggested Books:**

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	Stephen Boyd and Lieven Vandenberghe, "Convex Optimization". Cambridge University Press,	2004
2.	Suvrit Sra, Sebestian Nowozin and Stephen J. Wright, "Optimization for Machine Learning", PHI	2013
3.	Neal Parikh and Stephen Boyd, Proximal Algorithms, NOW	2013

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Computer Science and Engineering

1. **Subject Code:** CSN-515 **Course Title**: Data Mining and Warehousing
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Spring **7. Subject Area:** PEC
8. **Pre-requisite:** CS-102
9. **Objective:** To educate students to the various concepts, algorithms and techniques in data mining and warehousing and their applications.

10. **Details of the Course**

S.No.	Contents	Contact hours
1.	**Introduction to data mining:** Motivation and significance of data mining, data mining functionalities, interestingness measures, classification of data mining system, major issues in data mining.	3
2.	**Data pre-processing:** Need, data summarization, data cleaning, data integration and transformation, data reduction techniques —Singular Value Decomposition (SVD), Discrete Fourier Transform (DFT), Discrete Wavelet Transform (DWT), data discretization and concept hierarchy generalization.	6
3.	**Data warehouse and OLAP technology:** Data warehouse definition, multidimensional data model(s), data warehouse architecture, OLAP server types,data warehouse implementation, on-line analytical processing and mining,	4
4.	**Data cube computation and data generalization:** Efficient methods for data cube computation, discovery driven exploration of data cubes, complex aggregation, attribute oriented induction for data generalization.	4
5.	**Mining frequent patterns, associations and correlations:** Basic concepts, efficient and scalable frequent itemset mining algorithms, mining various kinds of association rules —multilevel and multidimensional, association rule mining versus correlation analysis, constraint based association mining.	6
6.	**Classification and prediction:** Definition, decision tree induction, Bayesian classification, rule based classification, classification by backpropagation and support vector machines, associative classification, lazy learners, prediction, accuracy and error measures.	6
7.	**Cluster Analysis:** Definition, Clustering Algorithms - partitioning, hierarchical, density based, grid based and model based; Clustering high dimensional data, constraint based cluster analysis, outlier analysis - density based and distance based.	6
8.	**Data mining on complex data and applications:** Algorithms for mining of spatial data, multimedia data, text data: data mining applications, social impactsof data mining, trends in data mining.	7
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	Marakas, George M. Modern data warehousing, mining, and visualization: core concepts. Upper Saddle River, NJ: Prentice Hall, 2003.	2003
2.	Pujari, Arun K. Data mining techniques. Universities press, 2001.	2001
3.	Lee, Mong Li, Hongjun Lu, Tok Wang Ling, and Yee Teng Ko. "Cleansing data for mining and warehousing." In International Conference on Database and Expert Systems Applications, pp. 751-760. Springer, Berlin, Heidelberg, 1999.	1999
4.	Wang, John, ed. Encyclopedia of data warehousing and mining. iGi Global, 2005.	2005
5	Gupta, Gopal K. Introduction to data mining with case studies. PHI Learning Pvt. Ltd., 2014.	2014
6	Tan, Pang-Ning, Michael Steinbach, and Vipin Kumar. Introduction to data mining. Pearson Education India, 2016.	2016

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Centre for Artificial Intelligence and Data Science

1. **Subject Code:** AID-552 **Course Title**: Deep Learning
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Both **7. Subject Area:** PEC
8. **Pre-requisite:** Machine Learning
9. **Objective:** The objective of this course is to learn deep learning algorithms, concepts, experiments, research along with their application on generic use cases.

10. **Details of the Course:**

S.No.	Contents	Contact Hours
1	Introduction to deep learning, logical computations with neurons, perceptron, backpropagation, historical trends, applications, and use-cases for industry	6
2	Deep Networks: Training a deep neural network (DNN), hidden layers, activation functions, fine-tuning neural network hyper-parameters	7
3	Custom Deep Neural Networks: vanishing/exploding gradient issues, reusing pre-trained layers, optimizers, l1 and l2 regularization, dropout	8
4	Convolutional neural networks (CNNs): convolutional layer, filters, stacking, pooling layer, CNN architectures	7
5	Recurrent neural networks (RNNs): recurrent neurons, unrolling, input and output sequences, training RNNs, deep RNNs, LSTM cell, GRU cell	7
6	Representation Learning and Generative Learning: Auto encoders: data representations, linear auto encoder, stacked auto encoders, variational auto encoders	7
Total		**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication/Reprint
1	Aurélien Géron, “Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems,”Second Edition, O'Reilly Media	2019
2	Ian Goodfellow, Yoshua Bengio, and Aaron Courville, “Deep Learning,” FirstEdition, MIT Press	2017
3	François Chollet “Deep Learning with Python,” First Edition, Manning Publication	2018
4	Rowel Atienza “Advanced Deep Learning with Keras,” First Edition, Packt Publishing	2018
5	Sudharsan Ravichandran “Hands-On Deep Learning Algorithms with Python,” First Edition, Packt Publishing	2019

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Centre for Artificial Intelligence and Data Science

1. **Subject Code:** AID-553 **Course Title:** Digital Image Processing
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weight:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Both **7. Subject Area:** PEC
8. **Pre-requisite:** Nil
9. **Objective:** The objective of this course is to introduce the fundamental techniques and algorithms used for acquiring, processing and extracting useful information from digital images.

10. Details of the Course

S.No.	Contents	Contact Hours
1.	**Introduction:** Signal processing overview; Image processing basics; Fundamental signals (1-D and 2-D); Classification of systems; Characteristics of LTI/LSI systems. Introduction to the DIP areas and applications.	4
2.	D**igital Image Fundamentals:** Human visual system and visual perception; Image sensing and acquisition Image file types; Pixel representation and spatial relationship	4
3.	Image Digitization: Sampling and quantization. Image Transforms: 2- D DSFT and 2-D DFT, 2-D discrete cosine transform (DCT), 1-D and 2-D Karhonen Loeve (KL) or principal component analysis (PCA) and 1-D and 2-D discrete wavelet transforms and relation to filter banks.	8
4.	Image Enhancement: Point and algebraic operations, edge detection and sharpening, filtering in the spatial and transformed domains. Rotation, interpolation, image filtering, spatial operators, morphological operators.	6
5.	**Image Segmentation:** Thresholding; Edge based segmentation; Region growing; Watershed transform. Image Restoration: Degradation models, inverse and pseudo-inverse filtering, 2-D Wiener filtering and implementation	6
6.	Image Compression and Encoding: Entropy-based schemes, Transform- based encoding, Predictive encoding and DPCM, Vector quantization, Huffman coding.	4
7.	Feature Extraction and Segmentation: Contour and shape dependent feature extraction, textural features, region-based and feature-based segmentation.	5
8.	Pattern Classification: Standard linear and Bayesian classifiers, supervised Vs unsupervised classification, classification performance index. Applications in satellite, sonar, radar and medical areas.	5
Total		**42**

11. Suggested Books:

S.No.	Name of Authors /Books / Publisher	Year of Publication/Reprint
1.	Gonzalez R. C. and Woods R. E., "Digital image processing," FourthEdition, Prentice Hall.	2017
2.	Lim J. S., "Two-dimensional signal and image processing," Prentice Hall.	1990
3.	Dudgeon D.E. and Merserau R. M., "Multidimensional digital signal processing," Prentice Hall Signal Processing Series.	1984
4.	Bose T., "Digital Signal and Image Processing", Wiley India.	2010
5.	Sonaka M., Hlavac V. and Boyle R., "Image Processing, Analysis and Machine Vision," Fourth edition, Cengage India Private Limited.	2017
6.	W. K. Pratt. "Digital Image Processing," Fourth Edition, John Wiley &Sons, New York.	2007

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Mathematics

1. **Subject Code:** MAN-628 **Course Title**: Evolutionary Algorithms
2. **Contact Hours:** **L:** 3 **T:** 0 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 3 **6. Semester:** Both **7. Subject Area:** PEC
8. **Pre-requisite:** Nil
9. **Objective**: To provide knowledge about basic concepts of Evolutionary Algorithms
10. **Details of the Course:**

S.No.	Contents	Contact Hours
1	**Genetic Algorithms:** Historical development, GA concepts – encoding, fitness function, population size, selection, crossover and mutation operators, along with the methodologies of applying these operators. Binary GA and their operators, Real Coded GA and their operators	12
2	**Particle Swarm Optimization:** PSO Model, global best, Local best, velocity update equations, position update equations, velocity clamping, inertia weight, constriction coefficients, synchronous and asynchronous updates, Binary PSO.	10
3	**Memetic Algorithms:** Concepts of memes, Incorporating local search as memes, single and multi-memes, hybridization with GA and PSO, Generation Gaps, Performance metrics.	5
4	**Differential Evolution:** DE as modified GA, generation of population, operators and their implementation.	5
5	**Artificial Bee Colony:** Historical development, types of bees and their role in the optimization process.	5
6	**Multi-Objective Optimization:** Linear and nonlinear multi-objective problems, convex and non – convex problems, dominance – concepts and properties, Pareto – optimality, Use of Evolutionary Computations to solve multi objective optimization, bi level optimization, Theoretical Foundations	5
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors /Books / Publisher	Year of Publication/Reprint
1.	Coello, C. A., Van Veldhuizen, D.A. and Lamont, G.B.: “Evolutionary Algorithms for solving Multi Objective Problems”, Kluwer.	2002
2.	Deb, K.: “Multi-Objective Optimization using Evolutionary Algorithms”, John Wiley and Sons.	2002
3.	Deb, K.: “Optimization for Engineering Design Algorithms and Examples”, Prentice Hall of India.	1998
4	Gen, M. and Cheng, R.: “Genetic Algorithms and Engineering Design”, Wiley, New York.	1997

5.	Hart, W.E., Krasnogor, N. and Smith, J.E. : “Recent Advances in Memetic Algorithms”, Springer Berlin Heidelberg, New York.	2005
6.	Michalewicz, Z.: “Genetic Algorithms+Data tructures=Evolution Programs”, Springer-Verlag, 3rd edition, London, UK.	1992

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Computer Science and Engineering

1. **Subject Code:** CSN-528 **Course Title**: Natural Language Processing
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Both **7. Subject Area:** PEC
8. **Pre-requisite:** Basic knowledge of Artificial Intelligence
9. **Objective:** To provide an understanding of the theoretical concepts of Natural Language Processing and prepare students for research or industry application of Natural Language Processing.

10. **Details of the Course**

S.No.	Contents	Contact hours
1.	Introduction to NLP, Corpus, Representation of Words, Preprocessing, Linguistic and Statistical Properties of Words, POS Tagging, Parsing, Performance Measures, Error Analysis, Confusion Matrix	6
2.	Probability and NLP, n-Gram, Language Model, Join and Conditional Probability, Chain Rule, Markov Assumption, Data Sparsity, Smoothing Techniques, Generative Models, Naive Bayes	6
3.	Distributed representation of words for NLP, Co-occurrence Matrix, Collocations, Dimensionality Reduction, Singular Value Decomposition	6
4.	Document Similarity, Inverted Index, Word2Vec, C-BoW, Skip-Gram Model, Sampling, Hierarchical Soft-max, Sequence Learning	6
5.	Neural Networks for NLP, Multi-Layer Perceptron, Activation Function, Gradient Descent, Sequence Modeling, Recurrent Neural Networks	6
6.	Gated Recurrent Unit, Long-Short Term Memory Networks, 1-D Convolutional Layer, Language Model using RNN, Forward Pass, Backward Pass	6
7.	Applications of NLP, Topic Modeling, Sentiment Analysis, Query Processing, ChatBoat, Machine Translation, Statistical Machine Translation, Neural Machine Translation, Spell Checker, Summarization	6
	Total	**42**

11. **Suggested Books:**

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	Manning, Christopher, and Hinrich Schutze. Foundations of statistical natural language processing. MIT press	1999
2.	Jurafsky, Dan. Speech & language processing. Pearson Education India	2000
3.	Smith, Noah A. Linguistic structure prediction. Morgan and Claypool	2011
4.	Kennedy, Graeme. An introduction to corpus linguistics. Routledge	2014

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Mathematics

1. **Subject Code:** MAN-653 **Course Title**: Numerical Optimization
2. **Contact Hours:** **L:** 3 **T:** 0 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 3 **6. Semester:** Both **7. Subject Area:** PEC
8. **Pre-requisite:** Nil
9. **Objective**: To provide knowledge about basic concepts of Numerical Optimization.
10. **Details of the Course:**

S.No.	Contents	Contact Hours
1.	Linear Programming: Review of various methods of linear programming	5
2.	Nonlinear Programming 1-D Unconstrained Minimization Methods: Golden Section, Fibonnacci Search, Bisection, Newton's Methods.	6
3.	Multi-dimensional Unconstrained Minimization Methods: Cyclic Coordinate Method, Hookes & Jeeves continuous and discrete methods, Rosenbrock method, Nelder & Mead method, Box's Complex method, Powell method, Steepest descent method, Newton's method, conjugate gradient method.	10
4.	Constrained Minimization: Rosen's gradient projection method for linear constraints, Zoutendijk method of feasible directions for nonlinear constraints, generalized reduced gradient method for nonlinear constraints.	6
5.	Penalty function methods: Exterior point penalty, Interior point penalty.	4
6.	Computer Programs of above methods. Case studies from Engineering and Industry, Use of software packages such as LINDO, LINGO, EXCEL, TORA, MATLAB	11
	Total	**42**

11. **Suggested Books:**

S.No.	Name of Authors/Book/Publisher	Year of Publication/Reprint
1.	Bazaraa, M. S., Sherali, H. D. and Shetty, C. M.:"Nonlinear Programming Theory and Algorithms", 2nd Edition, John Wiley and Sons.	1993
2.	Belegundu, A. D. and Chandrupatla, T. R. :"Optimization Concepts and Applications in Engineering", Pearson Education Pvt. Ltd.	2002
3.	Deb, K.: "Optimization for Engineering Design Algorithms and Examples", Prentice Hall of India.	1998
4	Mohan, C. and Deep, K.: "Optimization Techniques", New Age India Pvt. Ltd.	2009
5	Nocedal, J. and Wright, S. J.: "Numerical Optimization", Springer Series in Operations Research, Springer-Verlag	2000

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Centre for Artificial Intelligence and Data Science

1. **Subject Code**: AID-554 **Course Title**: Reinforcement Learning
2. **Contact Hours**: **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Both **7. Subject Area:** PEC
8. **Pre-requisite:** Nil
9. **Objective:** This course aims to understand several reinforcement learning algorithms and their applications, along with emerging research trends.
10. **Details of the Course:**

S.No.	Contents	Contact Hours
1	Basics of probability and linear algebra, Definition of a stochastic multi-armed bandit, Definition of regret, Achieving sublinear regret, UCB algorithm, KL-UCB, Thompson Sampling.	6
2	Markov Decision Problem, policy, and value function, Reward models (infinite discounted, total, finite horizon, and average), Episodic & continuing tasks, Bellman's optimality operator, and Value iteration & policy iteration	8
3	The Reinforcement Learning problem, prediction and control problems, Model-based algorithm, Monte Carlo methods for prediction, and Online implementation of Monte Carlo policy evaluation	8
4	Bootstrapping; TD(0) algorithm; Convergence of Monte Carlo and batch TD(0) algorithms; Model-free control: Q-learning, Sarsa, Expected Sarsa.	6
5	n-step returns; TD(λ) algorithm; Need for generalization in practice; Linear function approximation and geometric view; Linear TD(λ).	6
6	Tile coding; Control with function approximation; Policy search; Policy gradient methods; Experience replay; Fitted Q Iteration; Case studies.	8
Total		**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication/Reprint
1	Sutton, Richard S., and Andrew G. Barto. "Reinforcement learning: An introduction," First Edition, MIT press	2020
2	Sugiyama, Masashi. "Statistical reinforcement learning: modern machinelearning approaches," First Edition, CRC Press	2015
3	Lattimore, T. and C. Szepesvári. "Bandit algorithms," First Edition, CambridgeUniversity Press.	2020
4	Boris Belousov, Hany Abdulsamad, Pascal Klink, Simone Parisi, and Jan Peters "Reinforcement Learning Algorithms: Analysis and Applications," First Edition, Springer	2021
5	Alexander Zai and Brandon Brown "Deep Reinforcement Learning in Action," First Edition, Manning Publications	2020

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Centre for Artificial Intelligence and Data Science

1. **Subject Code**: AID-555 **Course Title**: Time Series Data Analysis
2. **Contact Hours**: **L:**3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage: CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits**: 4 **6. Semester:** Both **7. Subject Area:** PEC
8. **Pre-requisite:** Nil
9. **Objective:** The objective of this course is to understand and analyze time-series data facilitated by R programming

10. Details of the Course:

S.No.	Contents	Contact Hours
1	Basic Properties of time-series data: Distribution and moments, Stationarity, Autocorrelation, Heteroscedasticity, Normality	4
2	Autoregressive models and forecasting: AR, ARMA, ARIMA models	4
3	Random walk model: Non-stationarity and unit-root process, Drift and Trend models	4
4	Regression analysis with time-series data using R programming	5
5	Principal Component Analysis (PCA) and Factor Analysis	5
6	Conditional Heteroscedastic Models: ARCH, GARCH. T-GARCH, BEKK-GARCH	6
7	Introduction to Non-linear and regime-switching models: Markov regime-switching models, Quantile regression, Contagion models	5
8	Introduction to Vector Auto-regressive (VAR) models: Impulse Response Function (IRF), Error Correction Models, Co-integration	5
9	Introduction to Panel data models: Fixed-Effect and Random-Effect models	4
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication/Reprint
1	Chris Brooks “Introductory Econometrics for Finance,” Fourth Edition, Cambridge University Press	2019
2	Ruey S. Tsay “Analysis of Time-series data,” Third Edition, Wiley	2014
3	John Fox and Sanford Weisberg “An R Companion to Applied Regression,” Third Edition, SAGE	2018
4	Yves Croissant and Giovanni Millo “Panel Data Econometrics with R,” First Edition, Wiley	2018

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Centre for Artificial Intelligence and Data Science

1. **Subject Code:** AID-556 **Course Title:** Introduction to Compressive Sensing
2. **Contact hours**: **L:** 3 **T:** 1 **P:** 0
3. **Examination duration:** **Theory:** 3 **Practical:** 0
4. **Relative weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester**: Both **7. Subject area**: PEC
8. **Pre-requisite:** Knowledge of basic concepts in linear algebra, probability and constrained optimization.
9. **Objective:** The course introduces the basic concepts and mathematics behind compressed sensing and sparse recovery.

10. Details of the Course:

S.No.	Contents	Contact Hours
1.	**Mathematical Preliminaries:** Vector/matrix norms, Orthobasis expansion, Gaussian/Sub- Gaussian random variables and properties, basic concentration inequalities, basics of convex optimization and constrained optimization	8
2.	**Principles of sparse recovery:** Unique and stable sparse solutions of underdetermined linear systems, Unique sparse representation and uncertainty principle, Sensing matrix design, Null-space property (NSP), Mutual coherence based uniqueness and stable recovery guarantees, Restricted Isometry Property (RIP), Relationship between RIP and NSP, Johnson-Lindenstrauss lemma, Sparse recovery with random matrices	16
3.	**The compressed sensing problem & connections to sparse recovery:** Sparse representation of signals, compressible signals, union of subspaces	3
4.	**Sparse recovery methods:** Convex optimization algorithms - Basis Pursuit and LASSO, Greedy algorithms - Orthogonal Matching Pursuit (OMP), Thresholding-based algorithms- Iterative Hard Thresholding (IHT), MAP estimation-based sparse recovery methods	10
5.	**Applications:** Sub-Nyquist sampling, Image compression, Image-denoising, Sparse linear regression.	5
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors / Books / Publisher	Year of Publication/Reprint
1.	Michael Elad, ``Sparse and Redundant Representations - From Theory To Applications in Signal & Image Processing", 2010, Springer Publications.	2010
2.	Simon Foucart and Holger Rauhut, ``A Mathematical Introduction to Compressive Sensing", 2013, Birkhauser	2013
3.	Yonina Eldar and Gitta Kutyniok, ``Compressed Sensing: Theory and Applications", Cambridge University Press	2012

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Centre for Artificial Intelligence and Data Science

1. **Subject Code:** AID-557 **Course Title**: Neuromorphic computing with emerging memories and architectures
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Both **7. Subject Area:** PEC
8. **Pre-requisite:** Nil
9. **Objective:** This course will teach a student about devices, circuits and architectures for hardware implementation of neuromorphic systems
10. **Details of the Course**

S.No.	Contents	Contact hours
1.	**Introduction to Deep learning:** Deep Learning fundamentals, Training Deep Architectures, Sigmoid Neurons, Gradient Decent, Feedforward Neural Networks, Back-propagation, Principal component Analysis and its interpretations, Singular Value Decomposition, Batch Normalization, Introduction to Tensor flow.	6
2.	**Deep learning Algorithms:** Gradient Descent and Back-propagation, Improving deep network, Multi-Layer Neural Networks, The Challenge of Training Deep Neural Networks, Deep Generative Architectures. Mini-batches, Unstable Gradients, and Avoiding Over-fitting, Applying deep net theory to code, Introduction to convolutional neural networks for visual recognition.	6
3.	**Advanced Deep Architectures:** RNNs, RNNs in practice, LSTMs and GRUs, LSTMs and GRUs in practice, Reinforcement learning, Importance of unsupervised learning, Auto encoder.	6
4.	**Introduction to new trends in computing:** Numerical computing, Parallel computing, Cognitive computing, Approximate computing, Near memory and In-memory computing, Cloud, Fog, and Edge computing, Reconfigurable and heterogeneous computing.	8
5.	**ANN in hardware:** General-purpose processors, Digital accelerators, Digital ASIC approach, Optimization on data movement and memory access, Scaling precision, Leveraging sparsity, FPGA based accelerators, Analog/mixed-signal accelerators, Neural networks in conventional integrated technology, In/near-memory computing, Near-sensor computing, Neural network based on emerging non-volatile memory, Crossbar as a massively parallel engine, Learning in a crossbar, Case study: An energy-efficient accelerator for adaptive dynamic programming, Hardware architecture, On-chip memory, Datapath, controller, Design examples.	8

6.	**Neuromorphic computing with emerging memories:** Memristive and CMOS devices for neuromorphic computing, Multi-terminal transistor-like devices based on strongly correlated metallic oxides for neuromorphic applications, Bipolar analog memristors as artificial synapses for neuromorphic computing, Robust memristor networks for neuromorphic computation applications.	8
Total		**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	L. Deng and D. Yu, Deep learning: methods and applications, Now Publishers Inc. (1st edition)	2014
2.	M. A. Nielsen, Neural Networks and Deep Learning, MIT Press (1st edition)	2015
3.	I. Goodfellow, Y. Bengio, and A. Courville, Deep learning, MIT Press (2nd edition)	2016
4.	K. H. Mohamed, Neuromorphic Computing and Beyond: parallel, approximation, near memory, and quantum, Springer (1st edition)	2021
5.	Neuromorphic Computing and Beyond by K. S. Mohamed, Springer (1st edition)	2020
6.	J. Suñé, Memristors for Neuromorphic Circuits and Artificial Intelligence Applications, MDPI AG (1st edition)	2020

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Centre for Artificial Intelligence and Data Science

1. **Subject Code:** AID-558 **Course Title**: Data Stream Mining
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Both **7. Subject Area:** PEC
8. **Pre-requisite:** NIL
9. **Objective:** To introduce students to the various concepts and techniques in data stream mining
10. **Details of the Course**

S.No.	Contents	Contact hours
1.	**Introduction to Data Streams:** Data stream models, basic streaming methods, data synopsis, sampling, histograms, Wavelets, Discrete Fourier Transform	7
2.	**Clustering from Data Streams:** Basic concepts, Leader Algorithm, partitioning clustering,hierarchical clustering, grid clustering	7
3.	**Frequent Pattern Mining from Data Streams:** Search space, landmark windows, mining recent frequent item sets, sequence pattern mining, reservoir sampling for sequential pattern mining	7
4.	**Classification from Data Streams:** Decision Trees, VFDT- The base algorithm, extensions to the basic algorithm, exhaustive search, functional tree leaves, detecting changes	7
5.	**Change Detection in Data Streams:** Introduction, novelty detection as a one-class classification problem, positive Naïve Bayes, learning new concepts, approaches based on extreme values, decision structure, frequency distances, online novelty and drift detection	7
6.	**Case Study:** Time Series Data Streams – prediction, similarity, symbolic approximation	7
	Total	**42**

11. **Suggested Books:**

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	Gama, J., "Knowledge Discovery from Data Streams," 1st Ed., Chapman and Hall	2010
2.	Aggarwal, Charu C., "Data Streams: Models and Algorithms," Springer	2007
3.	Tan, P.N., Steinbach, M. and Kumar, V., "Introduction to Data Mining",Addison Wesley – Pearson.	2011
4.	L. Rutkowski, M. Jaworski, P, Duda, "Stream Data Mining: Algorithms and Their Probabilistic Properties," 1st Edition, Springer International Publishing.	2020

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Centre for Artificial Intelligence and Data Science

1. **Subject Code:** AID-559 **Course Title**: Stochastic Processes and their Applications
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Both **7. Subject Area:** PEC
8. **Pre-requisite:** Nil
9. **Objective:** To introduce concepts stochastic processes and their applications.
10. **Details of the Course**

S.No.	Contents	Contact hours
1.	**Review of Probability:** Probability measure, Borel-Cantelli lemma, multivariate random variable, Doob-Dynkin lemma, expectation, joint distribution and joint density functions, conditional expectation and its properties, conditional distribution and conditional density functions, independence of random variables, Markov inequality, Chebyshev inequality, convergence of random variables, law of large numbers, related applications and simulations.	7
2.	**Discrete time Markov chain:** Definition and construction, transition probability matrix, higher order transition probabilities, Chapman-Kolmogorov equation, dissection principle, classification of states, periodicity, solidarity properties, canonical decomposition, absorption probabilities, invariant measure and stationary distribution, limit distributions, renewal process, branching process, related applications and simulations.	11
3.	**Continuous time Markov chain:** Definition and construction, examples (pure birth process, birth-death process, uniformizable chain, etc.), stability and explosions, Markov property, dissection, backward and forward equations, generator, Chapman-Kolmogorov equation, stationary and limiting distributions, invariant measure, Laplace transform method, generating function technique, Point process, Poisson process, compound Poisson process, renewal process, Branching process, related applications and simulations.	11
4	**Brownian Motion:** Definition and construction (via random walk and Brownian bridge approximations), sample path properties, Brownian motion with drift, Ornstein-Uhlenbeck process, related applications and simulations.	6
5	**Martingales:** Filtration, stopping time, discrete time martingales with examples, optional stopping theorem, Doob's up-crossing inequality, Doob's convergence theorem, Doob's decomposition theorem, continuous time martingales with examples, related applications and simulations.	7
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication/ Reprint
1.	Zdzislaw Brzezniak and Tomasz Zastawniak, Basic stochastic processes, Springer-Verlag London	2005/7th
2.	Sindney Resnick, Adventures in stochastic processes, Birkhäuser Boston	2005/4th
3.	Paul Glasserman, Monte Carlo Methods in Financial Engineering, Springer	2003/1st
4.	Peter W. Glynn and Søren Asmussen, Stochastic Simulation: Algorithms and Analysis, Springer	2007/1st

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Centre for Artificial Intelligence and Data Science

1. **Subject Code:** AID-560 **Course Title**: Artificial Intelligence for Decision Making
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage: CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Both **7. Subject Area:** PEC
8. **Pre-requisite:** Nil
9. **Objective:** To introduce the concept of AI integrated decision making systems to the students.
10. **Details of the Course:**

S.No.	Contents	Contact Hours
1	**Introduction:** Review of decision making process in optimization and operations research models; overview of machine learning algo- rithms; ranking methods.	8
2	**Network flow models and their integration with AI algorithms**: Transportation and transshipment models; travelling salesman problem; vehicle routing; project management; integration of these models with ANN, Fuzzy logic, Genetic Algorithms.	10
3	**Multi criteria decision making (MCDM):** MCDM methods and their integration with fuzzy logic, ANN; Integration of MCDM methods with dimensionality reduction techniques like Principle Component Analysis, Singular Value Decomposition and page rank algorithms.	10
4	**AI integrated inventory models:** Basic inventory models; demand prediction for inventory management; reinforcement learning systems for full inventory management; AI algorithms for prediction and forecasting of inventory.	10
5	**Implementation:** Implementation of the above models in MATLAB/Python.	4
	Total	**42**

11. **Suggested Books:**

S.No.	Name of Authors/Book/Publisher	Year of Publication/Reprint
1.	F.S. Hillier and G.J. Liberman "Introduction to Operations Research". Tata McGraw Hill Education Private Limited.	2001
2.	H.A. Taha, "Operations Research, an Introduction", Pearson	2007
3.	Michael Carter, Camille C. Price and Ghaith Rabadi "Operations Research, A Practical Introduction", CRC press	2018
4.	Adiel Teixeira de Almeida, Emel Aktas, Sarah Ben Amor, João Luis de Miranda "Advanced Studies in Multi-Criteria Decision Making", CRC Press.	2020
5.	Gregory S. Parnel, Terry A. Bresnick, Steven N. Tani, Eric R. Johnson "Handbook of Decision Analysis", Wiley.	2013

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Centre for Artificial Intelligence and Data Science

1. **Subject Code:** AID-561 **Course Title:** AI for Earth Observation
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs):** **Theory:** 3 **Practical:** 0
4. **Relative Weight:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Spring **7. Subject Area:** PEC
8. **Pre-requisite:** Machine Learning
9. **Objective of Course:** Earth Observation is a key application area of AI. The objective of the course is to understand the application of AI in Earth Observation.
10. **Details of the Course:**

S.No.	Contents	Contact Hours
1	**Physical Fundamentals of Earth Observation:** Brief History of the Development of Earth Observation Sensors, Physical Properties of Electro-Magnetic Waves, Introduction to Electro-Magnetic Spectrum and Its Use in Earth Observation, Hyperspectral Remote Sensing **Sensors and Data:** Types of Resolutions, Types of Sensors: Optical, Microwave, Non- Imaging Sensors, UAV, Satellite Observation Geometries, Atmospheric Emissions	6
2	**Data Science Pipeline in Earth Observation:** Data Discovery and Organization of Data; Accessing Data; Exploratory Data Analysis and Visualization; Creation of Labels/Training Data; Analysis and Knowledge Discovery [Application of ML & DL]; AccuracyAssessment	6
3	**Analysis and Knowledge Discovery** using SVM, Random Forest, SOM, CNN, RNN, LSTM, GANs with: (a) Earth Observation Image Classification (b) Automatic Target/Object Detection and Classification (c) Time Series Analysis (d) Disaster Monitoring (e) Agriculture; Infrastructure; Weather and Space Weather	10
4	**Transfer Learning using AI models in Earth Observation**	4
5	**EO Data Requirements:** Database Techniques for Storing EO Data and Training Data; Relational Geospatial Big Data Systems	6
6	**Review of Current Research and Practices in AI for EO**	4
7	**Mini Project on the Application of AI for Analysing a Specific Domainin EO**	6
Total		**42**

<u>List of Tutorials</u>:

Tutorial 1: Access to different EO sensors, open EO datasets from different space agencies
Tutorial 2: Data discovery and accessing data using API, exploratory data analysis and visualization of EO data.
Tutorial 3: Application of ML models for EO data analysis and knowledge discovery.
Tutorial 4: Application of DL models for EO data analysis and knowledge discovery.
Tutorial 5: Transfer Learning of DL models in EO.
Tutorial 6: EO Scalable Data formats and geospatial big-data systems

11. Suggested Books

S.No.	Name of Authors/ Books/ Publisher	Year of Publication/Reprint
1	Thenkabail, P.S. "Remotely Sensed Data Characterization, Classification, and Accuracies": Three Volumes, First Edition, 2015, CRC Press	2016
2	Goodfellow, I., Courville, A., Bengio, Y. "Deep Learning", 2016, MIT Press	2017
3	Aurélien Géron. "Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems", Second Edition, 2019, O'Reilly	2019

12. Suggested software/computer languages to be used in the course

S.No.	Name of software
1	Python and Jupyter Notebooks; TensorFlow; PyTorch
2	Google Earth Engine
3	QGIS

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Centre for Artificial Intelligence and Data Science

1. **Subject Code:** AID-562 **Course Title:** AI for Investment
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs):** **Theory:** 3 **Practical:** 0
4. **Relative Weight:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Both **7. Subject Area:** PEC
8. **Pre-requisite:** Nil
9. **Objective of Course:** The objective of this course is to understand the application of Artificial Intelligence and Machine Learning techniques in financial markets, trading, and asset management.

10. Details of the Course:

S.No.	Contents	Contact Hours
1	Introduction to financial markets and market microstructure	4
2	Introduction to risk-return framework	4
3	Introduction to asset management and portfolio optimization	4
4	Market efficiency and behavioral finance	4
5	Prediction in Financial markets using AI and machine learning models, AI and machine learning in Trading execution and portfolio management	6
6	Credit scoring and credit modeling with non-linear machine learning models and deep learning	4
7	Model risk management and stress testing	4
8	Robo advisory, social and quantitative investing	5
9	Machine learning for asset management	4
10	AI and machine learning in regulatory compliance and supervision	3
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors/ Books/ Publisher	Year of Publication/Reprint
1	M. Dixon, I Halperin, and P. Bilokon "Machine Learning in Finance," First Edition, Springer	2020
2	Marcos Lopez "Advances in Financial Machine Learning," First Edition, Wiley	2018
3	Marcos Lopez "Machine Learning for Asset Managers," First Edition,Cambridge University Press	2020
4	Stefan Jansen "Machine Learning for Algorithmic Trading," Second Edition, Packt	2020
5	Elton and Gruber, "Modern Portfolio Theory," Ninth Edition, Wiley	2014

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Centre for Artificial Intelligence and Data Science

1. **Subject Code:** AID-563 **Course Title:** Applications of AI in Physics
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:**0
5. **Credits:** 4 **6. Semester:** Both **7. Subject Area:** PEC
8. **Pre-requisite:** Machine Learning
9. **Objective:** To enable the students to become an application engineer to apply AI tools to solve problems in cutting edge physics research.

10. **Details of Course:**

S. No.	Contents	Contact Hours
1.	Introduction to big data sets in Physics: Overview of different areas of physics and highlight areas where AI and ML is becoming an important tool of research; example of big data sets from physics; characterize the data sets from machine learning and AI point of view; why is Machine Learning difficult -setting up a physics problem as a ML task.	8
2.	Statistical physics ideas relevant for AI algorithms – Entropy, information, cost function, and minimization from a physics point of view.	6
3.	Application of AI tools to simple physics example - Ising model of Physics; application of selected supervised and unsupervised ML algorithms to Ising model. Physics-inspired algorithms for better machine learning.	8
4.	Application of AI tools to Condensed Matter Physics - Introduction to the area of research, Application of ML and AI tools to selected examples.	8
5.	Application of AI tools to Radiation Measurement and Modelling - Introduction to Radiation models, Measurement methods, and Application of ML and AI tools to selected examples.	6
6.	Sensor Designs and deep neural network: Plasmonic sensors modelling	4
	Total	**40**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication/ Reprint
1	Pankaj Mehta, Marin Bukov, Ching-Hao Wang, Alexandre G.R. Day, Clint Richardson, Charles K. Fisher, David J. Schwab, A high-bias, low-variance introduction to Machine Learning for physicists, by, Physics Reports 810 (2019)	2019
2	R. Feynman, R. Leighton, and M. Sands, The Feynman Lectures on Physics: The New Millennium Edition: Mainly Mechanics, Radiation, andHeat, v. 1, ISBN 9780465040858	1963
3	M. Nakhostin, Signal Processing for Radiation Detectors,Wiley, ISBN: 978-1-119-41022-	2017
4	Oliveira, L.C., Lima, A.M.N., Thirstrup, C., Neff, H.F., Surface Plasmon Resonance Sensors, A Materials Guide to Design, Characterization, Optimization, and Usage, Springer International Publishing, ISBN 978-3- 030-17485-9	2019

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Centre for Artificial Intelligence and Data Science

1. **Subject Code:** AID-564 **Course Title**: Medical Physics for AI
2. **Contact Hours:** **L:** 3 **T:** 0 **P:** 2
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 10-25 **PRS:** 25 **MTE:** 15-25 **ETE:** 30-40 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Both **7. Subject Area:** PEC
8. **Pre-requisite:** Machine Learning and Python Programming
9. **Objective:** To provide various applications of artificial intelligence in Medical physics.
10. **Details of the Course**

S.No.	Contents	Contact Hours
1.	**Introduction to Radiation Modalities:** Basics of Imaging Modalities, X-Ray Radiography, X-Ray CT, Ultrasonography, OCT, OCT Angiography, PET & SPECT, Magnetic Resonance Imaging, miscellaneous biomedical devices.	8
2.	**Human Anatomy for AI-aided Diagnostics:** General Anatomy, Bones & Joints, Muscle, Respiratory system, Digestive System, Cardiovascular system, Nervous system, Sense organs.	8
3.	**Functional Imaging Analysis:** Feature Selection, ML/DL model building, data preparation, model training, and model validation for various Modality, logistic regression & statistical inference, difference between biological, Experimental and clinical data. Limitations of AI	8
4.	**Radiotherapy and AI:** Brief introduction to diseases, computer-aided detection, classification, and diagnosis in radiology and auto-contouring, treatment planning, response modeling (radiomics), image guidance, motion tracking, and quality assurance in radiation oncology.	6
5.	**AI in Cardiology:** Brief introduction to diseases, CMR, Heart, Lungs, Head and Neck, RIC	6
6.	**Physiological Parameters and AI:** Data Analysis using EEG, ECG, SpO2 content.	6
	Total	**42**

11. List of Experiments:

1.	Read the DIACOM format from industrial / commercial MRI, CT and SPECT Machines.
2.	Identify the body part from given image and categorize into anatomical system.
3.	Identify the time series images to synchronize the random images according to human anatomy.
4.	Identify the anatomical and pathological abnormalities from a given image set.
5.	Identify the physiological abnormalities from a given data set.
6.	Manually segment MRI and CT Images of Heart, lungs and digestive system using Semi-automatic soft tools.
7.	Manually segment OCT Images of Eye using Semi-automatic soft tools.
8.	Segmentation of medical images using CNN.
9.	Identification of breathing pattern from ECG using CNN.
10.	Categorization of sleeping pattern from EEG using CNN.
11.	Deep Learning model and CT / OCT Image segmentation.

12. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication/Reprint
1	Guyton and Hall Textbook of Medical Physiology.	Second South Asia Edition 2019
2	Classification Techniques for Medical Image Analysis and ComputerAided Diagnosis, Academic Press.	1st Edition 2019
3	Pattern Classification of Medical Images: Computer Aided Diagnosis, Springer.	2017
4	Deep Learning in Medical Image Analysis: Challenges and Applications, Springer.	2020
5	Atam P. Dhawan, Medical Image Analysis. Wiley-IEEE Press.	2011
6	Adam Bohr, Artificial Intelligence in Healthcare, Academic Press ISBN 978-0-12-818438-7	2020

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Centre for Artificial Intelligence and Data Science

1. **Subject Code:** AID-565 **Course Title:** Computer Vision
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Both 7. **Subject Area:** PEC
8. **Pre-requisite:** Nil
9. **Objective:** To provide knowledge about various computer vision techniques and applications of machine learning in Computer Vision.
10. **Details of the Course:**

S.No.	Contents	Contact Hours
1.	**Image formation and camera calibration:** Introduction to computer vision, geometric camera models, orthographic and perspective projections, weak-perspective projection, intrinsic and extrinsic camera parameters, linear and nonlinear approaches of camera calibration	8
2.	**Feature detection and matching:** Edge detection, interest points and corners, local image features, feature matching and Hough transform, model fitting and RANSAC, scale invariant feature matching	6
3.	**Stereo Vision:** Stereo camera geometry and epipolar constraints, essential and fundamental matrix, image rectification, local methods for stereo matching: correlation and multi-scale approaches, global methods for stereo matching: order constraints and dynamic programming, smoothness and graph based energy minimization, optical flow	12
4.	**ML in Computer Vision:** Image Recognition; Tracking; Pre-trained CNN models in computer Vision; Open-CV; Applications of machine learning in computer vision	10
5.	**Structure from motion:** Camera self-calibration, Euclidean structure and motion from two images, Euclidean structure and motion from multiple images, structure and motion from weak-perspective and multiple cameras	6
Total		**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication/Reprint
1.	Forsyth, D. A. and Ponce, J., "Computer Vision: A Modern Approach",Prentice Hall, 2nd Ed.	2011
2.	Szeliki, R., "Computer Vision: Algorithms and Applications", Springer	2011
3.	Hartley, R. and Zisserman, A., "Multiple View Geometry in Computer Vision", Cambridge University Press	2003
4.	Gonzalez, R. C. and Woods, R. E., "Digital Image Processing", Prentice Hall, 3rd Ed.	2009
5.	Trucco, E. and Verri, A., "Introductory Techniques for 3-D ComputerVision", Prentice Hall	1998

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Centre for Artificial Intelligence and Data Science

1. **Subject Code**: AID-566 **Course Title**: Game theory
2. **Contact Hours**: **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage: CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Both **7. Subject Area:** PEC
8. **Pre-requisite:** Nil
9. **Objective:** The objective of this course is to understand algorithmic game theory and its applications using AI and machine learning techniques.

10. **Details of the Course:**

S.No.	Contents	Contact Hours
1	Introduction to Game Theory, Dominant Strategy Equilibria, Pure Strategy Nash Equilibria, computing Nash equilibrium	6
2	Mixed Strategy Nash Equilibria, Maxmin and Minmax Values, Matrix Games	6
3	Correlated Strategies and Correlated Equilibrium, Nash Bargaining Problem, Coalitional Games with Transferable Utility, The Core, Shapley Value, Nucleolus	10
4	Sequential learning in games, multi-agent learning using game theory	6
5	Introduction to Mechanism Design, Arrows Impossibility theorem, Gibbard-Satterthwaite Theorem, Mechanisms with Money	8
6	Myerson’s Lemma and VCG Mechanism	6
Total		**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication/Reprint
1	Martin J. Osborne “An Introduction to Game Theory,” First Edition, Oxford University Press.	2003
2	Y. Narahari “Game theory and mechanism design,” First Edition, World Scientific.	2014
3	Noam Nisan, Tim Roughgarden, Éva Tardos, Vijay V. Vazirani. “Algorithmic Game Theory,” First Edition, Cambridge University Press	2007
4	Ivan Pastine, Tuvana Pastine, and Tom Humberstone “Introducing Game Theory: A Graphic Guide,” First Edition, Icon Books Ltd	2017
5	Michael Maschler, Eilon Solan, Shmuel Zamir “Game Theory,” Second Edition, Cambridge University Press	2020

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Computer Science and Engineering

1. **Subject Code:** CSN-527 **Course Title**: Internet of Things
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Both **7. Subject Area:** PEC
8. **Pre-requisite:** Knowledge of computer networks
9. **Objective:** To impart the know-how of Internet of Things and their applications, architectures and protocols, building IoT applications/systems, securing the IoT systems, and their recent advances.

10. **Details of the Course**

S.No.	Contents	Contact hours
1.	**Basic concepts revisited:** Introduction to sensing & actuating, Basic networking, Wireless networks, Wireless sensor networks (WSN), Communication protocols, and other enabling technologies, IoT standards, Data storage & management issues and approaches, Cloud computing, Key challenges, research, and future directions of IoT, and security & privacy issues.	7
2.	**Embedded Systems:** Hardware and software of IoT, Microcontrollers, Understanding and programming Arduino, Raspberry Pi, NodeMCU, Lora, etc. Integrating microcontrollers with sensors and actuators, Building the IoT applications with any microcontroller.	6
3.	**IoT Architectures and Protocols:** Layers of communication, Architectures: State-of-the-art, IoT architecture reference models, Different views of IoT architectures and frameworks design, Protocols: Application protocols, Service discovery protocols, Infrastructure protocols, and other protocols. Understanding various types of protocols like HTTP, MQTT, CoAP, AMQP, 6LoWPAN, etc. Cross-layer implementations, and Data dissemination.	9
4.	**Support Technologies for IoT:** Big Data, Data Analytics, Artificial Intelligence, Mobile, Cloud, Software defined networks, 5G, and Fog/Edge computing. IoT integration with recent technologies. State-of-the-art. Design goals, challenges, and components.	8
5.	**Cyber Physical Systems:** Industry 4.0, Society 5.0, Design & use cases, Development, and implementation insights some examples like smart cities, smart homes, smart grids, smart agriculture, smart healthcare, smart transportation, smart manufacturing, and other smart systems. State-of-the-art. Conceptualizing the new IoT-based smart systems using a case study.	6
6.	**IoT Security & Privacy:** –, IoT Security and Privacy issues and challenges, Risks involved with IoT infrastructures, Trust in IoT platforms and other integrating technologies, Data aggregation, storage, retrieval, and other management issues including fault tolerance, interoperability, security, and privacy, Cyber-physical-systems and their security and privacy, Mitigation approaches.	6
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	Edited by: Buyya, Rajkumar, and Amir Vahid Dastjerdi, Internet of Things: Principles and paradigms. Elsevier/Morgan Kaufmann	2016
2.	Bahga, Arshdeep; Madisetti, Vijay, Internet of Things (A Hands-on-Approach), AbeBooks.com	2014
3.	Sohraby, Kazem, Daniel Minoli, and Taieb Znati. Wireless sensor networks: technology, protocols, and applications. John Wiley & Sons	2007
4.	Marinescu, Dan C., Cloud computing: theory and practice. Elsevier/ Morgan Kaufmann	2017

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Centre for Artificial Intelligence and Data Science

1. **Subject Code:** AID-567 **Course Title**: Introduction to Materials Informatics
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Both **7. Subject Area:** PEC
8. **Pre-requisite: Nil**
9. **Objective:** The course will introduce the students to the applications of data analysis and machine learning methods to the materials science problems. The course will provide an introduction to basic informatics and then focus on their application in materials synthesis, structural design and propertyoptimization.

10. **Details of the Course**

S.No.	Contents	Contact Hours
1	**Introduction to Materials Informatics:** History of materials development and need for new approaches, Multiscale materials modelling, need for data driven modelling, accelerated materials discovery and development, Quantitative structure-processing- property-performance relationships, knowledge discovery workflow for materials informatics, materials data science – structured and unstructured data, data mining, crystallography data base, Materials Genome, different sets of descriptors, nuts and bolts of materials informatics.	8
2	**Optimization - Calibration:** gradient based optimization, non- gradient based optimization, multi objective genetic algorithms (MOGA), Optimization of a multivariate model, applications to materials synthesis, processing, and transport phenomena.	8
3	**Predictive Modelling:** supervised learning, regression methods, classification methods, surrogate based optimization, prediction of material properties such as fatigue life, creep life.	8
4	**Descriptive Modelling:** Unsupervised learning, clustering analysis, clustering algorithms. Case studies: Estimation of microstrain, residual stress from diffraction, classification of materials based on physical properties.	8
5	**Limitations and Remedies:** Problem of small datasets in materials science, Data dimensionality reduction – principal component analysis, applications to 4D diffraction, spectroscopic data sets, high-throughput computational modelling of materials.	6
6	**Materials Selection for Engineering Design:** Systematic selection methods, trade-off analysis, vectors for materials development	4
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors /Books/ Publisher	Year of Publication/Reprint
1	Informatics for Materials Science and Engineering, Edited by Krishna Rajan, 1st edition, Butterworth-Heinemann, ISBN: 978-0- 123-94399-6	2013
2	Materials Informatics: Methods, Tools, and Applications, Edited by Olexandr Isayev, Alexander Tropsha and Stefano Curtarolo, 1st edition, Willey, ISBN: 978-3-527-34121-4	2019
3	S.R. Kalidindi, Hierarchical Materials Informatics, 1st edition, Butterworth-Heinemann, ISBN: 978-0-124-10394-8	2015
4	Nanoinformatics, Edited by Isao Tonaka, 1st edition, Springer Nature, ISBN: 978-9-811-07616-9 (Open access eBook)	2018
5	Information Science for Materials Discovery and Design, Edited by Turab Lookman, Francis Alexander and Krishna Rajan, 1st edition, Springer, ISBN: 978-3-319-23870-8	2016

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Computer Science and Engineering

1. **Subject Code:** CSN-519 **Course Title**: Social Network Analysis
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Spring **7. Subject Area:** PEC
8. **Pre-requisite:** Knowledge of computer networks
9. **Objective:** To introduce the basic notions used for social network analysis.
10. **Details of the Course**

S.No.	Contents	Contact hours
1.	Social Network Analysis: Preliminaries and definitions, Erdos Number Project, Centrality measures, Balance and Homophily.	4
2.	Random graph models: Random graphs and alternative models, Models of network growth, Navigation in social Networks	4
3.	Network topology anddiffusion, Contagion in Networks, Complex contagion, Percolation and information, Epidemics and information cascades	4
4.	Cohesive subgroups, Multidimensional Scaling, Structural equivalence, Roles and positions, Ego networks, Weak ties, Structural holes	6
5.	Small world experiments, Small world models, Origins of small world, Heavy tails, Small Diameter, Clustering of connectivity	6
6.	The Erdos Renyi Model, Clustering Models, Preferential Attachment	6
7.	Navigation in Networks Revisited, Important vertices and page rank algorithm, Towards rational dynamics in networks, Basics of game theory	6
8.	Coloring and consensus, biased voting, network formation games, network structure and equilibrium, behavioral experiments, Spatial and agent-based models	6
	Total	**42**

11. **Suggested Books:**

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	Wasserman, Stanley, and Joseph Galaskiewicz. Advances in social network analysis: Research in the social and behavioral sciences. Sage	1994
2.	Knoke, David, and Song Yang. Social network analysis. Sage Publications	2019
3.	Carrington, Peter J., John Scott, and Stanley Wasserman, eds. Models and methods in social network analysis. Vol. 28. Cambridge university press.	2005
4.	Liu, Bing. "Social network analysis." In Web data mining, pp. 269-309. Springer, Berlin, Heidelberg	2011

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Electronics and Communication Engineering

1. **Subject Code:** ECN-526 **Course Title:** Statistical Machine Learning for Variation-Aware Electronic Device and Circuit Simulation
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage: CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Spring **7. Subject Area:** PEC
8. **Pre-requisite:** Knowledge of basic concepts in probability and statistics
9. **Objective:** To familiarize students with the fundamental concepts, techniques and algorithms needed to perform stochastic simulation and uncertainty quantification of electronic devices, circuits and systems.
10. **Details of the Course**

S.No.	Contents	Contact hours
1.	**Introduction**: Introduction to stochastic modeling of general systems, key differences between stochastic simulation and classical deterministic simulation. The need for uncertainty quantification in general device, circuit, and system simulation.	2
2.	**Introduction to Random Variables:** Discrete and continuous random variables: distribution and density functions, conditional distributions and expectations, functions of random variables, statistical moments, sequence of random variables, central limit theorem, Gaussian and non-Gaussian correlation among random variables	3
3.	**Random Sampling Techniques**: Utilization of random sampling techniques for statistical analysis such as Monte Carlo, quasi-Monte Carlo, Latin hypercube sampling, analysis of computational complexity and convergence rate of different random sampling techniques	5
4.	**Statistical Machine Learning - Generalized Polynomial Chaos (PC) Theory**: Basic foundation of polynomial chaos, generalization of polynomial chaos for different known distributions, Wiener-Askey scheme of polynomials, generation of orthonormal basis functions using three-term recurrence series and Gram-Schmidt algorithm, training of polynomial chaos metamodels using quadrature techniques and least-squares linear regression. Deployment of PC theory for calculating statistical moments and density functions in linear and nonlinear VLSI as well as RF/microwave devices, circuits, and systems via test cases and illustrative examples.	6
5.	**Correlations in PC Theory:** Considering uncorrelated, Gaussian correlated, and non-Gaussian (mixed Gaussian model) correlated parametric variations.	5
6.	**Advanced PC theory:** Complexity analysis of PC theory and techniques: limitations of curse of dimensionality in PC theory, emphasis on sensitivity analysis-based dimension reduction, active subspaces, sliced inverse regression compressed sensing, partial least-squares algorithm, and multi-fidelity methods.	13

7.	**Inverse Problems:** Bayes rule, Bayesian formulation of inverse problems, prior and posterior distributions, calculation of maximum likelihood function using PC theory. Applications into inverse uncertainty quantification in linear/nonlinear devices, circuits and systems	8
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication/ Reprint
1.	D. Xiu, “Numerical Methods for Stochastic Computations: A Spectral Method Approach,” New Jersey: Princeton University Press	2010
2.	D. Dubois and H. Prade, “Possibility Theory: An Approach to Computerized Processing of Uncertainty,” vol. 2, New York, NY: Plenum Press	1988
3.	K. C. Gupta and Q. J. Zhang, “Neural Networks for RF and MicrowaveDesign,” Arctech House	2000
4.	A. Papoulis and S. Pillai, "Probability, Random Variables and Stochastic2017 Processes", 4th Edn., Mc Graw Hill.	2017
5.	R. Shen, S. X.-D. Tan, and H. Yu, Statistical Performance Analysis and Modeling of Nanometer VLSI. New York, NY:Springer	2012

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Centre for Artificial Intelligence and Data Science

1. **Subject Code**: AID-568 **Course Title**: ML and AI Applications in Earth Sciences
2. **Contact Hours**: L: 3 T: 1 P: 0
3. **Examination Duration (Hrs): Theory:** 3 **Practical**: 0
4. **Relative Weightage: CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Both **7. Subject Area:** PEC
8. **Pre-requisite:** Good foundation in Mathematics and Physics with specific exposure in Numerical Methods. Understanding of fundamental principles of Geology and Geophysics would be preferable.

9. **Objective:** To make the participants familiar with tools and techniques in Earth Sciences and the use of Machine Learning and Artificial Intelligence for optimizing the workflows for more accurate prediction of events and properties of the subsurface.

10. **Details of the Course**:

S.No.	Contents	Contact Hours
1	**Familiarization with Major Domains and Data Types in Earth Sciences:** Earthquake Seismology, Engineering Geology and Rock Mechanics, Reservoir Characterization, Paleontology	4
2	**General Introduction to ML and AI in Earth Sciences:** **ML and statistical pattern recognition:** Supervised learning (generative/ descriptive learning, parametric/ non-parametric learning, neural networks, Support vector machines), Unsupervised learning (clustering, dimensionality reduction, kernel methods); time series modelling, linear regression, regularization, linear classifiers, ensemble methods, neural networks, model selection and evaluation, scalable algorithms for big data, and data ethics. **Data science:** Extreme value statistics, multi-variate analysis, factor analysis, compositional data analysis, spatial information aggregation models, spatial estimation, geo-statistical simulation, treating data of different scales of observation, spatio-temporal modelling (geo-statistics).	6
3	**Automating Data Mining and Analysis in Seismology:** Basics of earthquake detection and phase picking using short-term average (STA)/long-term average (LTA); detection using waveform similarity: Network Matched Filtering/template matching, Fingerprint And Similarity Thresholding (FAST). Associating seismic phases across all stations using deep-learning techniques and combining the ones have the same origin source (PhaseLink). Generic workflow of data collection, preprocessing, model training, model evaluation, and production. Applications of ML in ground motion synthesis, and future directions.	6
4	**Classification of Earthquake Sources:** Using supervised learning for classifying earthquakes and finding their occurrence mechanism. Training dataset (waveforms) on different kinds of sources: earthquake, glacial, volcanic, landslide, explosion, etc. A brief discussion on seismic sources and radiation pattern of emerging waves.	4
5	**Deep learning (DL) based Seismic Inversion:** Theory of Seismic Inversion, Convolutional neural network (CNN) and fully connected network (FCN) architectures, Performance evaluation, Geophysical inversion versus ML, their applications to reflectivity inversion in seismic, Numerical examples.	4

6	**Automation in 3D Reservoir Property Prediction:** Data Mining, Automated Petrophysics, Statistical and Regression Methods for Elastic Property Prediction, ML and AI application in Geostatistics, Convoluted Neural Networks for Seismic Interpretation, Deep Learning for Impedance Inversion and Porosity Prediction.	4
7	**Data-Driven Analytics in Shale Resources:** Concepts of shale as source-reservoir-seal, Modeling Production from Shale, Shale Analytics, Decline Curve Analysis, Shale Production Optimization Technology (SPOT), Numerical Simulation and Smart Proxy	4
8	**Machine learning Applications in Engineering Geology and Rock Mechanics:** ML in rock mass characterization, Rock Mass Rating, Slope Mass Rating, Q-System, Engineering properties of rock and various rock engineering applications, AI in Landslides study.	6
9	**Separation and Taxonomic Identification of Microfossil:** 3D object recognition and segmentation applied to X-ray MicroCT images; Testing different algorithms for identifying and localizing individual microfossils in rock samples: Automated Computer Vision, Deep learning-based CNN semantic, and other segmentation architectures.	4
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publications/ Reprint
1	Patrick Wong, Fred Aminzadeh, and Masoud Nikravesh, Soft Computing for Reservoir Characterization and Modeling, Springer-Verlag Berlin Heidelberg GmbH	2002
2	William Sandham & Miles Leggett, Geophysical Applications of Artificial Neural Network and Fuzzy Logic, Springer	2003
3	C. Cranganu, H. Luchian, M. E. Breaban, Artificial Intelligent Approached in Petroleum Geosciences, Springer	2015
4	Shahab D. Mohaghegh , Data-Driven Analytics in Unconventional Resources, Springer	2017

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Electrical Engineering

1. **Subject Code:** EEN-581 **Course Title**: Intelligent Control Techniques
2. **Contact Hours:** **L:** 3 **T:** 0 **P:** 2
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 10-25 **PRS:** 25 **MTE:** 15-25 **ETE:** 30-40 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Both **7. Subject Area:** PEC
8. **Pre-requisite:** Control Systems
9. **Objective:** To introduce soft computing and intelligent control techniques and to apply these techniques to solve real-world modelling and control problems.
10. **Details of the Course**

S.No.	Contents	Contact hours
1.	Fuzzy Logic Systems: Fuzzy sets, operations on fuzzy sets, fuzzy relations, operations on fuzzy relation, linguistic variables, fuzzy if then rules, compositional rule of inference, fuzzy reasoning.	6
2.	Fuzzy Logic Control: Basic concept of fuzzy logic control, reasoning with an FLC, relationship to PI, PD and PID control,design of FLC: determination of linguistic values, construction of knowledge base, inference engine, tuning, fuzzification and defuzzification, Mamdani type models, Takagi-Sugeno-Kang (TSK) fuzzy models.	6
3.	Artificial Neural Networks: Perceptrons, perceptron training rule, gradient descent rule, multilayer networks and backpropagation algorithm, convergence and local minima, regularization methods, radial basis function networks, alternative error functions, alternative error minimization procedures, recurrent networks, extreme learning machines, unsupervised networks.	12
4.	Neural Networks for feedback Control: Identification of system models using neural networks, Model predictive control, feedback linearization and model reference control using neural networks, Neural Network Reinforcement Learning Controller, Adaptive Reinforcement Learning Using Fuzzy Logic Critic, Optimal Control Using NN.	8
5.	Hybrid algorithms: Neuro fuzzy systems, ANFIS and extreme learning ANFIS, derivative free optimization methods, genetic algorithm, particle swarm optimization, solution of typical control problems using derivative free optimization	8
Total		**40**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	Christopher M. Bishop, Neural Networks for Pattern Recognition", Oxford University Press, New York	1995
2.	S. Haykin, Neural Networks and Learning Machines, Prentice Hall	2009
3.	Driankov, Hellendoorn, Reinfrank, An Introduction to Fuzzy Control, Narosa Publishing House	1993
4.	Timothy J. Ross., Fuzzy Logic with Engineering Applications, John Wiley and Sons	2011
5.	SR Jang, CT Sun, E Mizutani, Neuro-fuzzy and soft computing: a computational approach to learning and machine intelligence, Prentice-Hall of India	2004

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Centre for Artificial Intelligence and Data Science

1. **Subject Code:** AID-569 **Course Title**: Applications of AI in Biology
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Both **7. Subject Area:** PEC
8. **Pre-requisite:** Nil
9. **Objective:** The course provides introduction to AI, Machine Learning and Deep learning algorithms, hands-on experience using Python and exposure to applications in genomics, medicine, biological and biomedical image analysis and in general computational biology and bioinformatics by discussion around published research.

10. **Details of the Course**

S.No.	Contents	Contact hours
1.	Relevance of ML in Biology and Medicine; Glimps of AI applications in Biology and Medicine; Handling biological and bioinformatics data; tools for data handling;	4
2.	Supervised Machine Learning applications in Biology and Medicine; Regression models based examples in Biology	6
3.	Applications of Decision trees, Random Forest, Support Vector Machines models in biology and medicine.	6
4.	Applications of Clustering Methods (k-means, Hierarchical, DBSCAN). Dimension Reduction: PCA, t-SNE. in Biology using research publications.	6
5.	Probabilistic Models, GANs, Hidden Markov Models, EM Algorithm. Paper examples using various algorithms	6
6.	Some well-known fully connected and deep networks and their use in Biological applications; case studies; Explore different ways Deep Learning is used in Biology through papers	8
7.	Some related case studies; Discussing/Presenting papers that that uses AI/ML/DL specifically related to biological applications	6
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication/Reprint
1	Kevin Murphy, “Machine Learning: A Probabilistic Approach” 1st Edition (The MIT Press)	2012, 2021
2	Pierre Baldi and Soren Brunak, “Bioinformatics: The Machine Learning Approach” 2nd Edition (The MIT Press)	2001
3	Tom M. Mitchell, “Machine Learning” (McGraw-Hill)	1997
4	Ian Good fellow, Yoshua Bengio and Aaron Courville, deeplearningbook.org(MIT Press)	Online book
5	Christopher M. Bishop “Pattern Recognition and Machine Learning” Springer	2006
6	The Elements of Statistical Learning: Data Mining, Inference, and Prediction. T.Hastie, R. Tibshirani, J. Friedman, 2nd Edition	2009

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Centre for Artificial Intelligence and Data Science

1. **Subject Code:** AID-570 **Course Title**: VLSI architectures for AI in CMOS Technology
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Both **7. Subject Area:** PEC
8. **Pre-requisite:** NIL
9. **Objective:** This course will teach the students about efficient implementation of computation intensive AI algorithms and operations using VLSI devices.

10. **Details of the Course**

S.No.	Contents	Contact hours
1.	**Algorithms for fast addition:** Basic addition and counting, Bit-serial and ripple-carry adders, Manchester carry chains and adders, Carry-look-ahead adders, Carry determination as prefix computation, Alternative parallel prefix networks, VLSI implementation aspects, Variations in fast adders, Simple carry-skip and Carry-select adders, Hybrid adder designs, Optimizations in fast adders, Multi-operand addition, Wallace and Dadda trees.	6
2.	**High speed multiplication:** Basic multiplication schemes, Shift/add multiplication algorithms, Programmed multiplication, Basic hardware multipliers, Multiplication of signed numbers, Multiplication by constants, Preview of fast multipliers, High-radix multipliers, Modified Booth's recoding, Tree and array multipliers, Variations in multipliers.	6
3.	**Real Arithmetic:** Representing the real numbers, floating-point arithmetic, The ANSI/IEEE floating point standard, Floating-point arithmetic operations, Rounding schemes, Logarithmic number systems, Floating-point adders, Barrel-shifter design, Leading-zeros/ones counting, Floating-point multipliers, Floating-point dividers, Arithmetic Errors and error control.	8
4.	**Implementation Topics:** Computing algorithms, Exponentiation, Approximating functions, Merged arithmetic, Arithmetic by table lookup, Tradeoffs in cost, speed, and accuracy. High-throughput arithmetic, Low-power arithmetic, Fault-tolerant arithmetic, Impact of hardware technology.	6
5.	**VLSI architectures:** Analog VLSI neural learning circuits, An analog CMOS implementation of Kohonen network with learning capability, Backpropagation learning algorithms for analog VLSI implementation, Analog implementation of the Boltzmann machine with programmable learning algorithms, VLSI design of the minimum entropy neuron.	8
6.	**VLSI Designs:** VLSI design of a 3-D highly parallel message-passing architecture, A dataflow architecture for AI, Processing in-memory design, COLIBRI: Coprocessor for LISP based on RISC.	8
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	B. Parhami, Computer Arithmetic: Algorithms and Hardware Designs, Oxford University Press, New York (2nd edition)	2010
2.	I. Koren, Computer arithmetic algorithms, CRC Press (2nd edition)	2018
3.	C. M. Bishop, Pattern Recognition and Machine Learning, Springer,Cambridge University Press (2nd edition)	2016
4.	M. Ercegovac and T. Lang, Digital arithmetic, Elsevier (1st edition)	2003
5.	M. G. Arnold, Verilog digital computer design: algorithms into hardware, Prentice Hall (2nd edition)	1999
6.	H. Kaeslin, Digital integrated circuit design: from VLSI architectures to CMOS fabrication, Cambridge University Press (2nd edition)	2009
7.	J. G. Delgado-Frias. and W. R. Moore, VLSI for neural networks and artificial intelligence, Plenum Press (1st edition)	2013

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Centre for Artificial Intelligence and Data Science

1. **Subject Code:** AID-583 **Course Title**: Data-driven Analytics for Smart Transportation Systems
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Both **7. Subject Area:** PEC
8. **Pre-requisite:** Nil
9. **Objective:** To familiarize with the applications of data science in traffic and transportation engineering and to demonstrate the applications of the data science in smart transportation planning

10. **Details of the Course:**

S.No.	Contents	Contact hours
1.	**Data Science in Transportation** Overview and Practical Applications; Transportation Data Sources; Data Collection; Data Preparation and Visualization.	4
2.	**Sensing and Data Mining for Smart Transportation Systems** Intelligent Transportation Systems, Incident Management Program, Efficient Emergency Vehicle Movement (Pre-Emption), Crash Detection, Reporting, and Clearance; Traffic Surveillance, Identification of Hotspots, Violation Detection; Road Network Asset Management, Inventory of Potholes, other Deficiencies; Adaptive Traffic Signal.	8
3.	**Data Analytics in Urban Transportation Planning** Basics of Urban Transportation Planning, Data Collection and Advanced Data Sources, Household Surveys, Demand Modeling using WiFi/ Bluetooth/ Call Data Record, Data Extraction and Analysis using APIs, Trip Distribution Modelling Approaches, Route Choice Models, Choice Set Generation Methods, Genetic Algorithms, Transportation Planning Example using Data-Driven Modeling and Simulation.	10
4.	**Urban Mass Transit System** Basics of Urban Mass Transit System, Static and Dynamic GTFS, Real-Time Transit, Travel Time Variability, Transit Reliability, Transit Planning using Smart-Card Data, Real-Time Accessibility Analysis.	6
5.	**Applications in Environmental Impact of Transport System** IOT based Air pollution, Real-Time Air Pollution Monitoring and Data Analysis, Placement of Mobile Sensors, Pollution Prediction using ML, Noise Data, Analysis of Key Parameters, Development of Policy Framework.	6
6.	**Crash Data Analytics** Crash Data, Data Preparation, Model Estimation, Real-Time Data-Driven Analysis; Emergency Vehicle Data, Crash Prone Stretches, Ambulance Deployment; Near-misses/Traffic Conflict Data, Surrogate Approach, Proactive Assessment and Safety Interventions.	8
	Total	**42**

11. Suggested books

S.No.	Name of Authors/Book/Publisher	Year of Publication/ Reprint
1.	Fumitaka Kurauchi, Jan-Dirk Schmöcker "Public transport planning with smart card data" CRC Press	2021
2.	Juan de Dios Ortúzar, Luis G. Willumsen "Modelling Transport", Wiley	2011
3.	Vukan R. Vuchic "Urban Transit: Operations, Planning, and Economics" Wiley	2005
4.	Constantinos Antoniou, Loukas Dimitriou, Francisco Pereira "Mobility Patterns, Big Data and Transport Analytics" Elsevier	2018
5.	Sara Moridpour, Alireza Toran Pour, Tayebeh Saghapour "Big Data Analytics in Traffic and Transportation Engineering: Emerging Research and Opportunities" IGI Global	2019
6.	Khaled R. Ahmed, Aboul-Ella Hassanien "Deep Learning and Big Data for Intelligent Transportation" Springer	2021
7.	Davy Janssens, Ansar-Ul-Haque Yasar and Luk Knapen "Data Science and Simulation in Transportation Research" IGI Global	2013