



Chapter 1 : Introduction to AI and ML	1-1 to 1-38
1.1 Introduction to Machine Learning.....	1-1
1.1.1 How does Machine Learning Work ?.....	1-3
1.1.2 Key Terms Associated with Machine Learning.....	1-5
1.1.3 Data Formats.....	1-5
1.1.4 DIKW Pyramid.....	1-6
1.1.5 Categories of Data Analytics.....	1-7
1.2 Types of Machine Learning.....	1-8
1.2.1 Supervised Learning.....	1-9
1.2.2 Unsupervised Learning.....	1-9
1.2.3 Reinforcement Learning.....	1-11
1.2.4 How to Choose the Right Machine Learning Algorithm ?.....	1-12
1.3 Issues in Machine Learning.....	1-13
1.4 Steps in Developing a Machine Learning Application.....	1-14
1.5 Introduction to Artificial Intelligence.....	1-19
1.5.1 Types of AI.....	1-20
1.5.2 History of AI.....	1-21
1.5.3 Comparison of AI with Data Science.....	1-22
1.5.4 Approaches to AI.....	1-22
1.5.4(A) Symbolic.....	1-24
1.5.4(B) Sub-symbolic (Connectionist Approach).....	1-27
1.5.4(C) Statistical.....	1-28
1.5.5 Need of AI in Mechanical Engineering.....	1-28
1.6 Basics.....	1-28
1.7 Application of Machine Learning and Artificial Intelligence.....	1-28
Chapter 2 : Feature Extraction and Selection	2-1 to 2-28
2.1 Feature and Feature Engineering.....	2-1
2.1.1 Data.....	2-1
2.1.2 Tasks.....	2-1
2.1.3 Models.....	2-2
2.1.4 Features.....	2-3
2.1.5 Feature Engineering.....	2-3



2.1.6	Data Engineering -vs- Feature Engineering.....	2-5
2.2	Dimensionality Reduction Techniques	2-6
2.2.2	Types of Dimensionality Reduction Techniques.....	2-8
2.3	Feature Transformation	2-8
2.3.1	Feature Construction	2-8
2.3.2	Quantization or Binning.....	2-8
2.3.3	Log Transform.....	2-10
2.3.4	Feature Scaling or Normalisation	2-11
2.3.5	Min-Max Scaling	2-11
2.3.6	Standardisation (Variance Scaling)	2-12
2.3.7	Encoding Categorical Variables	2-14
2.3.8	One-Hot Encoding.....	2-14
2.3.9	Dummy Coding.....	2-15
2.3.10	Feature Hashing.....	2-15
2.3.11	Handling Textual Features	2-17
2.3.12	Feature Extraction.....	2-18
2.4	Principal Component Analysis (PCA)	2-18
2.5	Feature (Subset) Selection	2-20
2.6	Key Drivers of Feature Selection.....	2-20
2.6.1	Measures of Feature Relevance	2-21
2.6.2	Measures of Feature Redundancy	2-22
2.7	Overall Feature Selection Process	2-24
2.8	Feature Selection Approaches.....	2-24
2.9	Ranking.....	2-25
2.10	Decision Tree	2-26
2.11	Applications of Feature Extraction and Selection Algorithms in Mechanical Engineering.....	2-26

Chapter 3 : Classification and Regression**3-1 to 3-108**

3.1	Classification Model.....	3-1
3.1.1	Decision Trees.....	3-2
3.1.2	Key Terms and Concepts.....	3-3
3.1.2(A)	Entropy	3-3
3.1.2(B)	Information Gain	3-6
3.1.2(C)	Gain Ratio	3-11
3.1.2(D)	Gini Index.....	3-15



3.2	Decision Tree Algorithms	3-28
3.2.1	The General Algorithm.....	3-28
3.2.2	ID3 Algorithm	3-29
3.2.3	C4.5 Algorithm	3-33
3.2.4	CART Algorithm.....	3-33
3.2.5	Evaluating a Decision Tree.....	3-34
3.3	Naïve Bayes.....	3-34
3.3.1	Bayes' Algorithm (Theorem).....	3-35
3.3.2	Naïve Bayes Classifier.....	3-36
3.3.3	Smoothing.....	3-44
3.3.4	Advantages of Naïve Bayes Classifier	3-46
3.3.5	Disadvantages of Naïve Bayes Classifier	3-46
3.4	Support Vector Machines (SVM)	3-47
3.4.1	Maximum Margin Linear Separators	3-48
3.4.2	Quadratic Programming Solution to Finding Maximum Margin Separators.....	3-48
3.4.3	Kernels for Learning Non-Linear Functions (Kernel Trick)	3-51
3.4.4	Comparison between Logistic Regression and SVM.....	3-52
3.5	Diagnostics (Evaluation Measures) of Classifiers	3-53
3.5.1	ROC Curve.....	3-56
3.5.2	Area Under the Curve (AUC).....	3-57
3.6	Additional Classification Methods.....	3-57
3.6.1	Bagging	3-57
3.6.2	Boosting.....	3-59
3.6.3	Random Forests.....	3-60
3.7	Regression Analysis.....	3-61
3.7.1	Linear Regression.....	3-62
3.7.1(A)	Use Cases (or Applications of) for Linear Regression	3-68
3.7.2	Logistic Regression	3-68
3.7.2(A)	Use Cases (or Applications of) for Logistic Regression.....	3-70
3.8	Support Vector Regression (SVR).....	3-70
3.8.1	Regression Trees.....	3-71
3.9	Reasons to Choose and Cautions.....	3-72
3.10	Additional Regression Models.....	3-73
3.11	Clustering.....	3-73



3.11.1	Properties of a Cluster.....	3-75
3.11.2	Types of Clustering.....	3-75
3.11.3	Use Cases (Applications) of Clustering.....	3-76
3.11.4	K-means.....	3-78
3.11.5	Determining the Number of Clusters.....	3-87
3.11.6	Diagnostics.....	3-91
3.11.7	Reasons to Choose and Cautions (Drawbacks / Challenges).....	3-92
3.12	k-Nearest Neighbours (kNN) Classification Algorithm.....	3-93
3.13	Applications of Classification and Regression Algorithms in Mechanical Engineering.....	3-94

Chapter 4 : Development of ML Model**4-1 to 4-9**

4.1	Problem Identification.....	4-1
4.1.1	Ranking (Learning to Rank).....	4-1
4.2	Steps in ML Modelling.....	4-2
4.3	Enhancing Performance of Classification.....	4-2
4.3.1	Cross-Validation.....	4-3
4.3.1(A)	Holdout Method.....	4-3
4.3.1(B)	k-Fold Cross-Validation.....	4-3
4.3.1(C)	Leave-P-Out Cross-Validation (LpOCV).....	4-4
4.3.2	Sub-Sampling.....	4-5
4.3.3	Hyperparameter Tuning Techniques.....	4-5
4.3.3(A)	What Do Hyperparameters Do?.....	4-6
4.3.3(B)	How is Hyperparameter Tuning Carried out?.....	4-6
4.3.3(C)	Hyperparameter Tuning Algorithms.....	4-7

Chapter 5 : Reinforced and Deep Learning**5-1 to 5-56**

5.1	Introduction to Neural Networks.....	5-1
5.1.1	Fundamental Concept.....	5-1
5.1.2	Biological Neuron.....	5-3
5.1.3	Evolution of Neural Networks (Hebb's Rule).....	5-4
5.2	Artificial Neural Networks (ANN).....	5-5
5.2.1	The Perceptron.....	5-10
5.2.2	The Bias Input.....	5-11
5.2.3	Multilayer Perceptron.....	5-12
5.2.4	Shallow and Deep Neural Network.....	5-13



5.3	Neural Network (NN) Architecture.....	5-14
5.4	Activation Functions	5-17
5.4.1	Types of Activation Functions	5-17
5.5	Learning Process.....	5-21
5.6	Convolution Neural Network (CNN or ConvNets).....	5-22
5.6.1	How do Convolutional Neural Networks Work ?.....	5-23
5.6.2	Convolutional Layer	5-23
5.6.3	Pooling Layer	5-25
5.6.4	Fully-Connected Layer	5-25
5.6.5	Convolutional Neural Networks and Computer Vision.....	5-25
5.7	Reinforcement Learning.....	5-25
5.7.1	Characteristics of Reinforcement Learning.....	5-26
5.7.2	Positive vs Negative Reinforcement Learning	5-30
5.7.3	The Reinforcement Learning Cycle.....	5-31
5.8	Markov Models.....	5-33
5.8.1	Steady State	5-37
5.9	Markov Decision Process (MDP).....	5-40
5.10	Reinforcement Learning Algorithms.....	5-42
5.10.1	Mathematical Foundation for Reinforcement Learning Algorithms	5-43
5.10.2	Learnable Functions in Reinforcement Learning	5-44
5.10.2(A)	Policy-Based Reinforcement Learning Algorithms	5-46
5.10.2(B)	Value-Based Reinforcement Learning Algorithms.....	5-46
5.10.2(C)	Model-Based Reinforcement Learning Algorithms.....	5-46
5.10.2(D)	Comparison between Policy-Based, Value-Based, and Model-Based Algorithms	5-47
5.10.3	On-Policy and Off-Policy Algorithms.....	5-48
5.10.4	Q-Learning (TD Learning).....	5-48
5.11	Application of Reinforced and Deep Learning in Mechanical Engineering.....	5-52

Chapter 6 : Applications**6-1 to 6-43**

6.1	Concept Building - Internet of Things (IoT)	6-1
6.1.1	Characteristics of IoT.....	6-2
6.2	IoT Vision.....	6-4
6.3	IoT and M2M.....	6-10
6.3.1	Introduction to M2M.....	6-10
6.3.1(A)	Applications of M2M	6-11



6.4	Things in IoT	6-11
6.5	Sensors, Actuators, and Smart Objects.....	6-13
6.5.1	Sensors.....	6-13
6.5.2	Types of Sensors.....	6-16
6.5.2(A)	Voltage Sensor.....	6-19
6.5.2(B)	Humidity Sensor.....	6-19
6.5.2(C)	Level Sensors	6-20
6.6	Actuators.....	6-21
6.6.1	Types of Actuators.....	6-21
6.7	Smart Objects.....	6-22
6.7.1	Common Smart Objects (IoT Devices).....	6-23
6.7.1(A)	Home Automation	6-24
6.7.1(B)	Industrial IoT	6-25
6.7.1(C)	Personal and Health Care	6-26
6.7.1(D)	Other Uses	6-26
6.8	Need of AI in Mechanical Engineering.....	6-27
6.9	Human Machine Interaction (Connected Factory).....	6-28
6.10	Predictive Maintenance and Health Management (Prognostics).....	6-31
6.11	Fault Detection (Machine Diagnosis and Prognosis)	6-34
6.12	Dynamic System Order Reduction (Model Order Reduction (MOR)).....	6-37
6.12.1	Image Based Part Classification.....	6-38
6.12.2	Process Optimisation	6-38
6.12.3	Material Inspection.....	6-40
6.12.4	Tuning of Control Algorithms	6-42
