Artificial Intelligence and Machine Learning Techniques in Engineering and Management

Komaragiri Srinivasa Raju · Dasika Nagesh Kumar

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Foreword

The 2024 Nobel Prize in Physics was awarded to John J. Hopfield and Geoffrey Hinton *for foundational discoveries and inventions that enable machine learning with artificial neural networks.* Two of the three winners of the 2024 Nobel Prize in Chemistry, Demis Hassabis and John Jumper, both from Google Deepmind, were cited for developing an AI model to solve a 50-year-old problem: predicting complex structures of proteins. These coveted prizes to Artificial Intelligence (AI) researchers bear testimony to the sweeping influence of AI.

Driven by extraordinary strides made over the years, especially in the past decade, AI now has the potential to fundamentally transform human civilization. Its importance is now recognized by societies across the globe as a key technology with the ability to solve some of the most complex societal and engineering problems of our times such as universal access to healthcare and education, efficient transportation, increased efficiency in providing e-governance services to the public, etc. To harness the power of AI, large-scale national and international efforts are underway.

AI has now matured to a level where AI applications are beginning to impact our daily lives: generative AI tools like ChatGPT and Gemini are now extensively used by researchers, students, and even public. Among the myriad of disciplines impacted by AI, engineering and management disciplines occupy a prominent position. AI and data science are now providing a major tool box to solve a wide spectrum of problems in engineering and management.

There is a large corpus of textbooks and research monographs on the foundations, theory, and advances in artificial intelligence, machine learning (ML), and deep learning (DL). There is, however, an urgent need for a book that provides a convenient, friendly, and yet rigorous treatment of AI and ML techniques to researchers, professionals, and students engaged in core engineering disciplines and also core management topics. This gap is splendidly filled by authors Srinivasa Raju and Nagesh Kumar, by bringing out their fine and timely textbook *Artificial Intelligence and Machine Learning Techniques in Engineering and Management*.

This is a nice book accessible to anyone seeking to clearly understand and rigorously apply AI techniques to problems in engineering and management disciplines. In particular, it will be a precious resource to undergraduate, master's, and doctoral

students applying AI and data science to their projects and research problems. The coverage of topics in machine learning and deep learning models is gentle and thorough, focussing on the main principles. The illustrative numerical examples, completely worked out, elevate the utility and understandability of the contents. The final chapter is especially valuable, with more than 200 case studies reviewed; this will be a goldmine to look up detailed studies of real-world problems.

The authors must be congratulated for conceptualizing a much needed AIML companion to students and researchers and for presenting the content in a lucid manner. For engineering and management audience, this book is a lovely resource on a live and lively subject.

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Preface

Artificial Intelligence (AI) is becoming familiar due to the minimum requirement of data, facilitating accurate predictions, and minimal necessity of understanding the physics behind input–output relationships. Its potential to tackle non-linear and complex problems with greater flexibility is an added advantage. Its applications in engineering, management, and allied fields are growing exponentially. Over time, numerous experts introduced books and developed blogs on the theme, which are primarily theoretical. However, the proposed book amalgamates relevant theory, numerical problems, case studies, and recent advances wherever possible. We believe that this new dimension will greatly benefit present-generation researchers and students.

The present book consists of seven chapters: (1) an introduction; (2) a description of performance indicators; (3) classical machine learning algorithms; (4) advanced machine learning algorithms; (5) fuzzy logic-based modelling algorithms; (6) emerging research areas, topics including, Blockchain, recent ML techniques, evolutionary algorithms, AI tools, the Internet of Things, big data, decision support systems, Taguchi design of experiments, data augmentation, and cross-validation; (7) representative case studies. The appendix covers representative AI tools, data sources related to AI, books, and journals on AI. The present book can support undergraduate, postgraduate, and Ph.D. students in AI, Data Mining, and Soft Computing in Engineering and Management and allied fields.

We are grateful to Prof. Yadati Narahari, Department of Computer Science and Automation, Indian Institute of Science, Bengaluru, who consented to write a Foreword for the book.

Special acknowledgments to Vogeti Rishith Kumar for posing thought-provoking, out-of-box questions, providing lots of input, and unstinting support wherever necessary. Heartfelt gratitude to Sistla Shashank, Prof. Alivelu Manga Parimi, Deepjyoti Deb, Dr. R. Madhuri, R. Bhavi Tej, Dr. Sriman Pankaj, Kathan Pranav Naik, Y. Sai Kiran, Pratyush Pandey, P. Sagar Subhash, Bhavesh Rahul Mishra, Harshal Nayan Rathi, Rahul Jauhari, Rishabh Daga, Ayushman Kar, Aakash Bansal, Kaustav Chatterji, and L. Ashoka Vardhan (who are presently or formerly associated with BITS) who contributed immensely for the book. Also, thanks to Prof. M. Janga Reddy (IIT Bombay), Prof. Shishir Gaur (IIT BHU), Prof. D. Graillot (EMSE France), Prof. D. V. Morankar (College of Military Engineering, Pune), and many others who supported us from time to time.

We referred to a number of research papers and many blog sites related to AI. Overall, they shaped the book in its present form. We acknowledge LINDO SYSTEMS INC. for providing access to the LINGO software trial version, Scopus for research data analysis, and Python for programming support.

We have incorporated a few portions from some of our published research papers, either utilizing CC BY 4.0 and CC BY-NC-ND 4.0 licenses under the open access category or taking permissions in case of non-open access category journals. All these research papers were referred at suitable places. We wholeheartedly express gratefulness to the publishers of these journals, IWA, Springer, ASCE and Wiley. We extend thanks to all the co-authors of the papers for their constant encouragement and support in realizing our plan to publish this book.

We made the best possible efforts to quote all the sources in the form of acknowledgements or references, but still, some would have been missed. We will incorporate them upon notice in the upcoming editions.

Professor Raju appreciates the institute leadership for providing the necessary ecosystem for writing this book. He acknowledges the help of his wife, Gayathri Devi; Daughter, Sai Swetha; and son, Sai Satvik; and Parents, Gopala Rao and Varalakshmi, for their unstinting support. He thanks Prof. A. Vasan, Subbulakshmi Vasan, Dr. K. Nagajyothi, and Mr. B. Surendra for their motivating support. Professor Nagesh acknowledges the support of his wife Padma, daughter Sruthi, son Saketh, and parents Subrahmanyam and Lakshmi.

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Dr. Dasika Nagesh Kumar is Professor at the Department of Civil Engineering at the Indian Institute of Science (IISc), Bengaluru, India. He completed Ph.D. from IISc Bangalore. He is presently working as Edward M. Curtis Visiting Professor, Lyles School of Civil and Construction Engineering, Purdue University, West Lafayette, USA, on sabbatical from IISc. He is Fellow of the Indian Academy of Sciences, Indian National Science Academy, and National Academy of Sciences. He held the Prof. Satish Dhawan Chair Professor position from 2018 to 2021. He was the Chairman, Centre for Earth Sciences, IISc, during 2014–2020. He was a Boyscast Fellow with Utah Water Research Laboratory, Utah State University, Logan, UT, USA, in 1999 and Visiting Professor in EMSE, St. Etienne, France in 2012. His research interests include climate hydrology, climate change, water resource systems, deep learning, evolutionary algorithms, fuzzy logic, MCDM, and Remote sensing and GIS applications in water resource engineering. He has supervised 10 Post-docs

and 22 Ph.Ds. He is co-author of eight books and published more than 240 papers. He has received funding support of more than INR 50 crores for sponsored research. He is Editor-in-chief of *Journal of Water and Climate Change* and Associate Editor of *ASCE Journal of Hydrologic Engineering*.

Acronyms

AARLF	Average Absolute Relative Loss Function
ACO	Ant Colony Optimization
AdaBoost	Adaptive Boosting
AI	Artificial Intelligence
ALO	Ant Lion Optimizer
ANFIS	Adaptive Neuro-Fuzzy Inference System
ANN	Artificial Neural Networks
ANOVA	Analysis of Variance
AUC-ROC	Area Under the Curve-Receiver Operating Characteristic
Bi-LSTM	Bi-directional Long Short-Term Memory
BP	Back-Propagation
BRT	Boosted Regression Tree
CART	Classification And Regression Tree
CatBoost	Categorical Boosting
ChatGPT	Chat Generative Pre-trained Transformer
CNN	Convolutional Neural Networks
CNN-LSTM	Convolutional Neural Networks-Long Short-Term Memory
CS	Constraint Space
CSA	Cuckoo Search Algorithm
DE	Differential Evolution
DHL	Differential Hebbian Learning
DL	Deep Learning
DNN	Deep Neural Networks
DSS	Decision Support Systems
DT	Decision Tree
DV	Decision Variables
EA	Evolutionary Algorithms
ELM	Extreme Learning Machine
FCM	Fuzzy Cognitive Mapping
FCMe (or FCA)	Fuzzy Cluster Means (or Fuzzy Cluster Analysis)
FFBP	Feed-Forward with Back-Propagation

FIS	Fuzzy Inference Systems
FL	Federated Learning
FN	False Negative
FNR	False Negative Rate
FP	False Positive
FPR	False Positive Rate
FSS	Fractional Skill Score
GA	Genetic Algorithm
GB	Gradient Boosting
GBDT	Gradient Boosting Decision Tree
GRNN	General Regression Neural Network
GRU	Gated Recurrent Unit
GWO	Grey Wolf Optimizer
HC	Hierarchical Clustering
HGSO	Henry Gas Solubility Optimization
HL	Hebbian Learning
ICA	Imperialist Competitive Algorithm
IoT	Internet of Things
KGE	Kling Gupta Efficiency
KMe	K-Means clustering
KNN	K-Nearest Neighbour
LFM	LSTM-RF Framework with Multitasking
LFS	LSTM-RF Framework with Single tasking
LGBoost	Light Gradient Boosting
LiR	Linear Regression
LP	Linear Programming
LR	Logistic Regression
LSTM	Long Short-Term Memory
MARS	Multivariate Adaptive Regression Spline
ML	Machine Learning
MLiR	Multiple Linear Regression
MLP	Multilayer Perceptron
MSLF	Mean Square Loss Function
NAS	Neural Architecture Search
NB	Naïve Bayes
NGBoost	Natural Gradient Boosting
NHL	Non-linear Hebbian Learning
NLP	Natural Language Processing
Non-LP	Non-linear Programming
NRMSLF	Normalized Root Mean Square Loss Function
NSE	Nash–Sutcliffe Efficiency
NSGA-II	Non-dominated Sorting Genetic Algorithm-II
NSLF	Normalized Standard Loss Function
OF	Objective Function
PCA	Principal Component Analysis

PoET	Proof of Elapsed Time
PoS	Proof of Stake
PoW	Proof of Work
PSO	Particle Swarm Optimization
QP	Quadratic Programming
R_0	The highest possible R based on the perception of the user
R (or CC)	Correlation Coefficient
RBF	Radial Basis Function
ReLU	Rectified Linear Unit
RF	Random Forest
RMSLF	Root Mean Square Loss Function
RNN	Recurrent Neural Networks
RSA	Reptile Search Algorithm
RSM	Response Surface Methodology
SA	Simulated Annealing
SC	Subtractive Clustering
SHAP	SHapley Additive exPlanations
SI	Swarm Intelligence
SS	Search (Decision) Space
SSLF	Sum of Square Loss Function
SVM	Support Vector Machine
SVR	Support Vector Regression
TEE	Trusted Execution Environment
TLBO	Teaching Learning-Based Optimization
TN	True Negative
TNR	True Negative Rate
TP	True Positive
TPR	True Positive Rate
TSS	Taylor Skill Score
WGAN	Wasserstein Generative Adversarial Networks
WI	Willmott Index
WNN	Wavelet Neural Networks
XGBoost	EXtreme Gradient Boosting

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