FROM THEORY TO IMPACT: NEW VISIONS ACROSS DISCIPLINES

FIRST EDITION
2025

Editor-in-Chief
Daniel James

A S D F

ASDF UK

ISBN 978-81-951337-7-2

9 788195 133772

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FTI 2025

FIRST EDITION 2025

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By

ASDF, UK

Financially Sponsored By

Association of Scientists, Developers and Faculties, India

Editor-in-Chief

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Editors:

Anbuoli Parthasarathy and Katsuo Shichirou

Published by

Association of Scientists, Developers and Faculties
Address: 483 Green Lanes, London N13 4BS. England. United Kingdom.
Email: admin@asdf.res.in || www.asdf.international

From Theory to Impact: New Visions Across Disciplines 2025 (FTI 2025)

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Editor-in-Chief: **Daniel James**
Editors: **Anbuoli Parthasarathy and Katsuo Shichirou**

Cover Design: **Saravanan Velayudham**

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ISBN-13: 978-81-951337-7-2
ISBN-10: 81-951337-7-0

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MACHINE LEARNING VS DEEP LEARNING

S MADHU PRATTIKA

B.Sc. Artificial Intelligence and Machine Learning

ABSTRACT

Machine learning (ML) and deep learning (DL) are the two fundamental approaches to AI. ML and DL help computers learn from data and make decisions. ML uses algorithms to analyse data, whereas DL trains neural networks to do more complex tasks such as image and speech recognition. Here, we discuss the applications, challenges, and trends in ML and DL.

Keywords: Machine Learning (ML), Deep Learning (DL), Artificial Intelligence (AI), Data, Ethics.

INTRODUCTION

Machine learning and Deep learning are areas of artificial intelligence (AI). They are techniques that allow AI to provide human-level intelligence in computer programs, making challenging objectives simpler and more predictable [1]. Machine learning (ML) is all about teaching computers to make their choices wiser with experience. It's a usage of AI that allows machines to learn and adapt without direct coding [5]. The main objective is becoming more specific by doing the same actions and desired outcomes.

Deep Learning (DL) is making Artificial Intelligence smart by artificial neural networks inspired by the human brain. The networks are made up of several layers of interconnected neurons, which extract features hierarchically automatically. DL learns to learn features from massive datasets, such as complex high-dimensional data such as images, speech, and video.

Each on its own or combined, these technologies have the potential to fuel innovation across sectors. In healthcare, they assist in diagnosing illness, administering precision medicine, and detecting drugs. In banking and financial services, they assist in fraud detection, credit scoring, and enabling high-frequency trading.

Through the combination of deep learning and machine learning, companies can tackle more sophisticated challenges and create more intelligent, more adaptive AI systems that enable next-generation technology [4].

MACHINE LEARNING

It is the process of getting computers to learn how to analyze information, identify patterns and learn how to do tasks better with experience. Unlike traditional programming where instructions are explicitly stated. ML systems learn through experience and modify their behavior accordingly in solving real-world problems in business [6]. The primary purpose of ML is to achieve high accuracy in prediction and decision-making. This is done by designing the action of the system to closely align with desired results measured in terms of various performance metrics such as precision, recall and accuracy [7]. The core ingredients of ML are:

Data: High quality diverse datasets are the constituents of ML systems used for training accurate models [8].
Algorithms: Mathematical procedures that are meant to act on data and produce desired outputs [6].

Experience: Iterative learning mechanisms enable the system to learn as time passes through decreasing errors in prediction [7].

WORKING OF MACHINE LEARNING

Data collection and pre-processing: Data is obtained from many sources such as data bases, IoT devices or user interactions. Pre-processing invoice cleaning, normalization and conversion of the data to render it free from inconsistencies, missing values or outliers [9].

Feature Engineering: Choosing and selecting the most significant variables or features that affect the output. This process can involve creating new variables or dimensionality reduction using methods like PCA (Principal Component Analysis) [9].

Model Selection: Algorithm selection based on the type of problem such as linear regression for predictive problems, K-Nearest Neighbors (KNN) for classification, K-Means for clustering [10].

Training The Model: Feeding labelled or unlabelled data into the chosen algorithm. The model adjusts its internal parameters to minimize prediction errors [9].

Evaluation: Testing models performance in terms of measures like

Accuracy: Ratio of correct predictions.

F1-Score: Balance between precision and recall.

Mean Squared Error (MSC): Measures prediction error for regression models [10].

Deployment: Placing the model trained to production system to make it capable of giving real-time prediction or decision [9].

TYPES OF MACHINE LEARNING

Supervised Learning

The algorithm is trained on the labeled data when supervised learning occurs, where input data is provided with correct related (labels). It is intended to learn a mapping function from the inputs to outputs and make prediction on unseen data. Includes training an example model to known input-output pairs of the data [9].

Examples: Spam filtering, Sales prediction.

Algorithms: Lenear regression, Support Vector Machines (SVM) [10].

Unsupervised Learning

Is provided with unlabeled data and is requested to find hidden patterns or data structures in unsupervised learning. Operates on unlabeled data to identify to discover hidden structures [11].

Examples: Market basket analysis, Customer segmentation.

Algorithms: K-Means Clustering, Principal Component Analysis (PCA) [11].

Semi-Supervised-Learning

This is a half-supervised approach where the model is trained using a mix of labeled and unlabeled data. A small amount of data is labeled and the remaining is not. Merges small labeled sets and huge unlabeled sets [11].

Applications: Identifying frauds, medical images.

Algorithm: Self training, Generative models [11].

Reinforcement Learning

Reinforcement learning is agent that learns taking a sequence of actions in the environment to maximise cumulative reward. It discovers through the obtained feedback in reward or penalty [12].

Uses: Robotics, Game-playing Artificial Intelligence and Driverless cars.

Methods: Q-Learning, Deep Q-Networks (DQN) [12].

Self-Supervised Learning (Newer Type)

This type of learning utilizes unlabeled data to internally generate labels to allow the model to self-train. It is commonly classified as a subtype of supervised learning [13].

Examples: Language models (e.g., GPT, BERT), Vision tasks (e.g., SimCLR, BYOL) [13].

DEEP LEARNING

Deep Learning (DL) is a branch of artificial intelligence (AI) and machine learning that is concerned with the training of artificial neural networks (ANNs) to mimic human information processing. It comprises multiple layers of neurons that gradually extract patterns and features from raw data [14].

DL performs optimally with the handling of much unstructured data such as images, text, and audio. DL powers applications such as image classification, natural language processing, speech recognition, and autonomous systems [15].

DL's building blocks are:

Automatic Feature Learning: Learns the features of raw data automatically by itself without manual assistance [14].

Hierarchical Processing: Applies a stack of layers to learn simple and sophisticated patterns [14].

High Accuracy: Exhibits state-of-the-art performance on the majority of AI activities [15].

DEEP LEARNING WORKING

Data Preparation: Requires huge dataset of labeled examples in case of supervised tasks

Model Design: Selection of appropriate neural network architecture (e.g., CNN, RNN) [16].

Training with Backpropagation: Adapting the weights and bias using techniques such as gradient decent.

Evaluation: Quantifying the performance using criteria such as accuracy, precision, recall and F1-score.

Deployment: Deployment of trained models in applications like speech recognition image classification [15].

Types Of Deep Learning

Convolutional Neural Networks (CNNs)

CNNs are used to handle grid-like data such as images. They extract spatial features such as objects, texture and edges using convolutional layers. Utilize polling layers for dimension reduction keeping significant features [13].

Application: Autonomous cars, tumour detection, face recognition

Recurrent Neural Network (RNNs)

RNNs are well-suited to sequential data, where the current input depends on previous inputs. They utilize loops within their structure to hold onto previous inputs.

Variants:

Long Short-Term Memory (LSTM)

Gated Recurrent Units (GRU).

Use: Speech recognition, Stock price prediction.

Feedforward Neural Networks (FNNs)

FNNs are the simplest type of neural networks, where data travels one way from input to output [15].

Use: Bank fraud detection, Regression and classification problems.

Generative Adversarial Networks (GANs)

GANs consists of two networks: a generative and a discriminator. The generative produces new data and the discriminator verifies it's authenticity.

Application: Image generation, Data augmentation, Style transfer[16].

Autoencoders

Autoencoders are unsupervised neural networks used for encoding data into a compact form and reconstructing it. Learn efficient data representation. Useful for dimensionality reduction.

Application: Anomaly detection, Image denoising, Feature extraction.

Transformer Networks

Transformers are robust architectures for sequence data, which have substituted RNNs and LSTMs in most applications. They utilize self-attention mechanisms to handle sequence more effectively [16].

Applications: Language models, Image recognition.

Deep Belief Network (DBNs)

DBNs are generative models that learn a feature hierarchy by stacking Restricted Boltzmann Machines (RBMs) layers. Pretrained layer-wise for better initialization [12].

Application: Handwriting recognition, Image recognition.

Radial Basics Function Networks (RBFNs)

RBFNs are feedforward neural networks using radial basis function as activation functions. Can be used for regression problems. Focus on higher-dimensional interpolation [16].

Use: Time-series forecasting, Function approximation.

Spiking Neural Networks (SNNs)

SNNs mimic how neurons in the human brain fire bursts of information. SNNs are bio-inspired and deal with information in real-time, [12].

Use: Neuromorphic computing, Robotics.

Difference Between Machine Learning and Deep Learning:

Aspect	**Machine Learning**	**Deep Learning**
Data Dependency	Works with small to medium data sets.	Requires large amount of labeled data.
Feature Engineering	Requires manual feature extraction.	Extracts features automatically.
Complexity	Simpler models with	Highly complex models with

	fewer parameters.	millions of parameters.
Computation Needs	Requires moderate computation power.	Needs powerful GPUs or TPUs for training
Training Time	Faster training time.	Longer due to complex architectures.

APPLICATION OF MACHINE LEARNING AND DEEP LEARNING HEALTHCARE

ML: Prediction of disease from patient history and patient data. Prediction of risk of chronic diseases like diabetes or coronary heart disease.

DL: Diagnosis based on medical images. Drug discovery and drug design based on generative model-based method. Prediction of disease from genomic sequence analysis.

Agriculture

ML: Prediction of crop yield from weather and soil data. Predictive models for disease and pest [17].

DL: Disease prediction in crops using image interpretation. Monitoring crop health using images from drones for precision farming.

ML: Predictive maintenance through equipment data analysis. Process optimization to increase production efficiency[21].

DL: Defect detection through image-based quality monitoring. Robotic assembly line functionality.

Education

ML: Dynamic adaptive learning system, which adapts material dynamically based on the performance of students. Student dropout rate and academic performance prediction,

DL: Automatic grading of assignments and exams. Virtual speech-enabled tutors and NLP.

Cybersecurity

ML: Malware detection using behavioral analysis [5], Network traffic analysis-based intrusion detection systems.

DL: Identification of sophisticated cyberattacks using pattern recognition. Real-time threat detection for encrypted traffic

CHALLENGES IN MACHINE LEARNING AND DEEP LEARNING

Data Challenges

ML: Needs high-quality, well-formatted data. Does not work with small data or incomplete data.

DL: Requires very large amounts of labeled data, which are expensive and time-consuming. Difficulty in processing real-time or streaming data effectively.

Model Training Challenges

ML: Overfitting and underfitting are prevalent. Needs good feature engineering.

DL: High computational expense. Large models are expensive to train and have long training times [18].

Interpretability and Explainability

ML: Simpler to interpret for less complicated models. But still difficult for more complicated models such as Random Forests [19].

DL: More likely to be a "black box" and thus more difficult to explain decisions.

Ethical Issues:

ML: Algorithmic bias can lead to unfair results. Privacy issues in data collection and usage.

DL: More possibility of bias and ethics due to use of huge data sets. Models can happen to encode and reinforce violent tendencies unintentionally.

Development and Maintenance:

ML: Simple to execute but can possibly require frequence update since data will continue changing.

DL: Difficult to execute in live environment. It requires massive resources to retrain and update now and then [20].

FUTURE TRENDS IN MACHINE LEARING AND DEEP LEARING

AUTOMATION

ML: AutoML computerizes operations such as feature engineering, hyperparameter optimization, building model and lessening expert human intervention [21].

DL: Auto-creation of the architecture of the neural network and setup of auto pipeline make it easy for deep learning to be employed in challenging tasks.

Edge Computing and IoT:

ML: Deployed models in edge devices provide less delay response and diminish reliance on cloud infrastructures.

DL: In fact, small models such as Mobile Net allow deep learning to execute on device with low resources, paving the way for intelligent city and IoT use cases [20].

QUANTUM INTEGRATION

ML: Quantum algorithms enhance optimization procedures, speeding up problem-solving in finance and logistics.

DL: Quantum-boosted deep learning that enhances efficiency in dealing with large data and model training [19].

Ethical AI

ML: Provides accountability and fairness for AI-based decisions especially in high-risk industries such as lending and hiring.

DL: Combats dangers such as deepfakes and maintains AI models guaranteeing user privacy and social conventions.

Augmented Intelligence:

ML: Enhances human capabilities by insights for improved decision-making especially in manufacturing and education industries.

DL: Empowers sophisticated cognition systems, robots and immersive virtual assistants for solving real-world challenges [18].

CONCLUSION

In short, Machine Learning (ML) and Deep Learning (DL) are both revolutionary technologies under the category of Artificial Intelligence with unique strengths and applications [19]. While ML is the one to use for developing prediction models from structured data, DL is the most suitable to handle gigantic unstructured data sets (images, texts, and sound files). Both these technologies are transforming how various industries, from the health industry to cybersecurity, forecast, make decisions, and automate more accurately [21].

However, while offering tremendous potential, they are limited by data requirements, model complexity, and interpretability. In the future, through evolution, automation, edge computing, and possibly quantum integration, the AI landscape continues to evolve, releasing further opportunities for industries to be challenged to solve complex real-world problems with these technologies [17].

In the long run, the future of ML and DL will broaden and be used to develop tasks that will create more effective, reliable, and responsive AI systems that will revolutionize technology beyond anyone's imagination.

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ASSOCIATION OF SCIENTISTS, DEVELOPERS AND FACULTIES

483 GREEN LANES, LONDON N13 4BS

INDIA | THAILAND | SOUTH KOREA | UNITED KINGDOM

+44 20 81445548 | ASDF@ASDF.INTERNATIONAL | WWW.ASDF.INTERNATIONAL

£ 99

ISBN 978-81-951337-7-2

/ASDFInt /ASDFInt /ASDFInt /ASDFInt /ASDFInternational /ASDFInt /ASDFInt