Deep learning applications

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Objectives

By the end of this course, students will be able to

1. Remember: Identify and define key deep learning concepts, functions, and architectures.
2. Understand: Explain differences between ML and DL, and interpret how neural networks operate.
3. Apply: Implement deep learning models using Keras and TensorFlow for real datasets.
4. Analyze: Compare and evaluate different models, and diagnose issues such as overfitting.
5. Evaluate: Justify model choices and optimization techniques with evidence.
6. Create: Design and develop innovative deep learning applications and research projects.

I Unit 02: Machine learning

1. Introduction

Machine Learning (ML) is a core branch of Artificial Intelligence that enables computers to learn from data without being explicitly programmed. Instead of following fixed rules, machine learning systems use algorithms to analyze patterns, make predictions, and improve performance over time as they are exposed to more data. This ability to learn from experience makes machine learning a powerful tool in many fields, including economics, management, healthcare, finance, and marketing.

In this unit, we will explore the fundamental concepts of machine learning, how it differs from traditional programming, and why it is essential in modern data-driven decision-making. One of the key aspects of machine learning is the type of learning it employs, which determines how the system processes data and generates knowledg

2. what's machine learning

Machine Learning (ML) is a branch of Artificial Intelligence (AI) that focuses on developing algorithms and statistical models that allow computers to perform tasks without explicit instructions. Unlike traditional programming, where a programmer defines a set of rules for the computer to follow, ML systems learn patterns and relationships from data. Over time, these systems improve their performance as they are exposed to more data, adapting to changes and providing increasingly accurate outputs.

In essence, machine learning is about teaching machines to learn from experience. The "experience" is the data, and the learning process consists of identifying patterns, correlations, or trends in this data to make predictions, classify information, or generate insights. Machine learning can handle very large datasets and discover non-obvious relationships that humans might overlook.

ML algorithms are generally categorized into three main types:

1. Supervised Learning: The model is trained on labeled data (input-output pairs) to predict outcomes or classify data.
2. Unsupervised Learning: The model identifies hidden structures or patterns in unlabeled data, such as clustering or association.
3. Reinforcement Learning: The model learns by interacting with an environment, improving its decisions based on rewards or penalties.

2.1. Machine Learning in Auditing

Machine Learning can greatly improve the efficiency and accuracy of auditing by **automating the detection of anomalies, errors, or fraudulent transactions** in financial data. Traditional audits rely heavily on sampling, which means auditors examine only a small portion of all transactions. ML enables the analysis of **entire datasets**, uncovering patterns that would be difficult or impossible to detect manually.

Example Scenario: Detecting Fraudulent Transactions in a Company's Accounting Records

1. **Data Collection:** The audit team collects transactional data, including invoices, payments, journal entries, and ledger records. Features such as transaction amount, date, vendor, frequency, and payment method are included.

2. **Model Selection:** A supervised learning algorithm (like Random Forest or Gradient Boosting) is chosen if labeled data exists (transactions previously identified as fraudulent or legitimate). Alternatively, an unsupervised model (like an Autoencoder or Isolation Forest) can detect unusual patterns without prior labels.
3. **Training the Model:** The ML algorithm learns to identify patterns associated with irregular transactions, such as unusual amounts, abnormal timing, or rare vendor combinations.
4. **Prediction and Analysis:** The model assigns a fraud risk score to each transaction. High-risk transactions are flagged for further review by auditors.
5. **Decision-Making:** Auditors focus their attention on flagged transactions, which **reduces manual effort**, increases audit coverage, and improves fraud detection accuracy.

Benefits in Auditing:

- Detects **fraud and errors** across all transactions, not just samples.
- **Saves time** and resources for auditors.
- Provides **data-driven insights** to improve internal controls and compliance processes.
- Enhances the **accuracy and reliability** of financial reporting.

Concrete Example from Research:

The study “Enhancing Fraud Detection in Accounting through AI: Techniques and Case Studies” demonstrates how deep learning models can detect fraudulent accounting entries, significantly improving the efficiency of audits. (fepbl.com, 2024[1])

2.2. Machine Learning Approaches

Machine Learning can be divided into three main types: Supervised Learning, Unsupervised Learning, and Reinforcement Learning. Each type differs in how the model learns from data and the type of problems it can solve. In auditing, these techniques can be applied to detect fraud, identify anomalies, and optimize audit strategies.

a) Supervised Learning

Supervised Learning is a type of machine learning where the model learns from labeled data, meaning that each example in the training set includes input features and the correct output. The model uses this data to learn the relationship between inputs and outputs and can then predict results for new, unseen data. This type of learning is ideal for classification and regression tasks.

i) Main Algorithms of Supervised learning

- Linear Regression: A statistical model that establishes a linear relationship between input variables and a continuous output variable, used for quantitative predictions.
- Logistic Regression: A model used to classify observations into two categories by predicting the probability of belonging to each class.
- Decision Trees: A tree-like structure where each node splits the data based on a condition on the attributes, enabling step-by-step classification or prediction.
- Random Forest: An ensemble of independent decision trees whose combined votes reduce overfitting and improve prediction accuracy.
- Support Vector Machines (SVM): An algorithm that separates classes by finding the hyperplane that maximizes the margin between different categories in a multidimensional space.
- Neural Networks (MLP, CNN, etc.): Artificial networks composed of interconnected layers of neurons capable of modeling complex, nonlinear relationships between inputs and outputs.

1. https://www.fepbl.com/index.php/farj/article/view/1232?utm_source=chatgpt.com

Example of application: A company wants to detect fraudulent transactions. Historical transaction data is labeled as "fraudulent" or "legitimate." Using a Random Forest algorithm, the model learns patterns associated with fraud (e.g., unusual amounts, rare vendors, irregular timing) and predicts which new transactions are likely fraudulent, allowing auditors to focus on high-risk cases.

b) Unsupervised Learning

Unsupervised Learning is used when the data is unlabeled, and the goal is to discover hidden patterns or structures. The model identifies clusters, groups, or anomalies without prior knowledge of the correct outputs.

i) Main Algorithms of unsupervised learning

- K-Means Clustering: Partitions data into k clusters by grouping similar points together and minimizing intra-cluster distance.
- Hierarchical Clustering: Creates a hierarchy of clusters by progressively merging or dividing groups based on their similarity.
- Principal Component Analysis (PCA): A dimensionality reduction technique that transforms variables into a set of orthogonal components while preserving the maximum variance.
- Autoencoders: Neural networks that learn to reconstruct input data after compression, often used for anomaly detection.
- Isolation Forest: An anomaly detection algorithm that isolates unusual observations using random binary trees.

Example of application: Auditors want to identify unusual accounting entries in a large dataset. An Isolation Forest algorithm is applied to all entries to detect anomalies. The system automatically flags transactions that deviate significantly from normal patterns, helping auditors focus on potential errors or fraud.

ii) Reinforcement Learning

Reinforcement Learning (RL) involves an agent learning to make decisions by interacting with an environment. The agent receives rewards or penalties based on its actions and learns over time to maximize cumulative rewards. This approach is useful for sequential decision-making problems.

1 Main Algorithms of reinforcement learning

- **Q-Learning:** RL method where an agent learns the value (Q-value) of each action in each state to maximize future rewards.
- **Deep Q-Networks (DQN):** Extension of Q-Learning that uses deep neural networks to approximate Q-values in high-dimensional environments.
- **Policy Gradient:** The agent learns directly the probability of taking each action to maximize cumulative reward.
- **Actor-Critic Methods:** Combines Policy Gradient and Q-Learning; the "Actor" proposes actions, and the "Critic" evaluates their value to guide learning.

An audit team wants to optimize the audit process by selecting the most important transactions to review. A reinforcement learning agent is trained to choose transactions that maximize fraud detection while minimizing time and effort. The agent gradually learns which types of transactions are most likely to be problematic, improving the efficiency of audits.

Conclusion

Deep Learning has emerged as a transformative technology in both economics and management. By enabling the analysis of massive and complex datasets, it allows organizations, financial institutions, and governments to make more informed, data-driven decisions. Across multiple domains — from macroeconomic forecasting and financial risk management to marketing, operations, accounting, and sustainability planning — deep learning has demonstrated its ability to uncover hidden patterns, predict trends, and automate complex tasks.