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Full Length Review Article

A Comprehensive Review of Artificial Intelligence, Machine Learning, and Generative Models for Intelligent Decision-Making Across Modern Computational Domains

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Abstract: *Machine Learning (ML) and Artificial Intelligence (AI) have found their way into the perennial categories of valuable tools used to make intelligent decisions in data-intensive and complex spaces. The ongoing accelerated research and development in the supervised learning field, deep learning, generative algorithms, and signal processing applications have facilitated effective solutions to financial, medical, intelligent transportation system, Internet of Things (IoT), and cyber-physical infrastructures. Rule-based and statistical methods prove often to be not scalable or generalizable in regard to heterogeneous, in large dimensional, and dynamically changing data. This in turn is leading to the adoption of data-driven and learning-based solutions that can be used to aid in prediction, automation and adaptive intelligence. The current review paper provides a synthesis of the most recent research advances in the field of AI-based decision-support systems and dwells upon the algorithmic core, specific areas of application, and trends. The article summarizes the findings of papers dealing with financial anomaly detection, learning analytics, radiomics-aided medical imaging, IoT-powered intelligent systems and generative artificial intelligence as well as cutting-edge signal processing systems. The most critical challenges associated with the interpretability, data quality, scalability, security, and ethical governance are under consideration. The review ends with an overview of the future research directions to explainable, multimodal, and responsible AI systems that will be able to work properly in the real-world settings.*

Keywords: *Artificial Intelligence; Machine Learning; Deep Learning; Generative AI; Intelligent Systems; Financial Analytics; Medical Imaging; IoT; Responsible AI*

1. Introduction

The fast digitization of the modern society has led to levels of data that have never been created before through financial transactions, medical image systems, intelligent sensors, and communication networks as well as, user interrelations. To obtain actionable insights of such data, it is necessary to have computational models that learn the not simple patterns, can deal with uncertainty, and can adjust to the changing environments. The emergence of Artificial Intelligence (AI) and Machine Learning (ML) has become a fundamental technology that allows such abilities.

Computational systems that were developed previously were mostly based on understanding by hand and statistical assumptions, making them less applicable in practice to noisy, nonlinear and high-dimensional real-world systems. Deep and supervised learning types of machine learning methods have overcome these drawbacks by allowing automatic learning of features and finding patterns in raw data. Recognition of financial anomalies, prediction of time-series with multivariate, and automated decision-making in critical infrastructures are recent studies that have proven the efficiency of deep learning models (Ghori, 2018; Ghori, 2019).

Meanwhile, the medical image analysis based on AI has transformed healthcare as a paradigm. Radiomics systems have also allowed the quantitative description of disease patterns using imaging data, which is significantly more diagnostically and prognostically accurate (Amudala Puchakayala et al., 2023). Learning-based techniques of optimization and anomaly detection have also been used to improve efficiency, safety, and reliability in intelligent transportation systems and networks based on IoT (Sheela, 2023).

Generative Artificial Intelligence in particular has brought additional features as more recently prediction is no longer a requirement, and content generation, simulation, or even synthetic data can be created. The advances have led to the emergence of personalization and data augmentation as well as scenario modeling, especially in controlled sectors like the finance and medical care fields

(Puchakayala, 2024). The purpose of this paper is to have a single review of these developments and analyze how AI-based approaches are converging in various areas of application.

2. Literature Review

2.1 AI and Machine Learning in Financial Decision Systems

The nature of financial data is complex, high-dimensional, and time-dependent and therefore this becomes challenging with the traditional models of analysis. The use of machine learning techniques has portrayed a great promise in mitigating these challenges since they learn latent patterns and temporal dependencies. Frameworks based on deep learning with anomaly detection have been demonstrated to be far more effective in detecting irregular and fraudulent financial behaviour than other types of statistical and rule-based systems (Ghori, 2018).

Another important field of the applications of the time-series forecasting in financial and energy systems is also necessary. Multivariate environments Hybrid models based on classical statistics, which involve using machine learning algorithms including Random Forests, Gradient Boosting, and Recurrent Neural Networks, have enhanced accuracy in making predictions (Ghori, 2019). To some extent, more current research has involved applying Large Language Models (LLM) to financial analytics, especially to detect a fraud and predict risks, but has also identified the emergence of new vulnerabilities that will appear because of adversarial manipulation and model security (Ghori, 2023).

Auditing Generative models have also boosted financial intelligence by making it possible to generate synthetic data and to respond to customers in an adaptive way. The generative AI-driven models have proven to be more flexible and aware of specific contexts than rule-based systems and have enhanced the provision of more personalized and scalable financial services (Puchakayala, 2024). Besides, GAN-based imputation methods have resolved the issue of missing or incomplete financial data to enhance the performance of downstream models (Bansal et al., 2025).

2.2 Supervised Learning and Predictive Analytics

Supervised machine learning continues to be a paradigm of predictive analytics in a variety of fields. Research on predicting the performance of learners revealed that the classification algorithms, including Logistic Regression, Support Vector Machines, and Random Forest, can be successfully used to predict the data of structured behavioral and demographic data to facilitate early intervention strategies (Ghule, 2025; Ghule et al., 2024).

Although supervised learning models are effective, they are characterized by three issues namely scalability, real time deployment and interpretability. These problems are quite pertinent especially in decision-support systems where transparency and accountability must be provided. It is stressed in the ongoing research to combine explainable AI methods and hybrid modeling strategies to compromise performance and interpretability.

2.3 AI in Healthcare and Medical Imaging

The use of AI in the healthcare system has become increasingly popular due to progress in its medical imaging and the availability of data. The machine learning systems based on radiometics have facilitated the identification of quantitative characteristics in medical images and have rendered useful biomarkers to detect the disease as well as analyse its progression (Saha et al., 2025; Shalini and Patil, 2021). CT-based radiomics studies have shown a high change of detecting respiratory condition and forecasting pathogenic alterations against their traditional indicators of clinical importance (Puchakayala et al., 2024; Sheela and Shalini, 2024).

Information shortage is one of the challenges in medical imaging. GANs have also been successfully utilized to create realistic medical imagery, which can be used to enlarge the training data and enhance the accuracy of classification in dermatological and other vision tasks (Sheela et al., 2023). These methods pig on the bigger initiatives to utilize generative models to achieve healthcare analytics robustness and generalization.

2.4 Intelligent Transportation Systems and IoT-Enabled Frameworks

Intelligent transportation systems and IoT systems create references of constant heterogeneous data flows, including sensors and cars and communication infrastructure. Resource allocation and optimization strategies have been suggested as based on machine learning in order to deal with the problem of spectrum congestion, energy-efficient resource allocation, and Quality of Service limits in vehicular networks (Sheela et al., 2023).

The IoT-based systems also enjoy un-supervised learning-based anomaly detector and security systems. Studies have also examined the use of blockchain-based malware detection and secure exchange of data AI frameworks, and found adaptive intelligence to be important in the context of cyber-physical systems (Shalini et al., 2023).

2.5 Signal Processing, Optimization, and Multimodal Learning

Machine learning and highly advanced signal processing have made the acquisition of highprecision decision systems in safety-critical applications possible. Hybrid models that combine wavelet transforms, empirical mode decomposition, and optimal classifiers have shown impressive results when used to detect the driver drowsiness (Sardesai and Gedam, 2025).

In addition to single-modality data, there is a multi-correlated phenomenon of multimodal machine learning as an important research field. Combining images, signals, text, and sensor information allows making stronger and contextual decisions. According to systematic reviews, the representation learning, data fusion, and co-learning should be defined as the most prominent issue in multimodal systems, and the applications are used in healthcare, finance, and autonomous technologies (Sardesai et al., 2025).

3. Integrated AI Architectures for Decision-Making

The trend is toward modern intelligent systems being contemplated in terms of integrated and hybrid AI architectures, as jointly application (combining different learning paradigms), to the complexity of the real-world environment. These architectures combine supervised learning, deep learning, generative models and optimization methods in order to promote robustness, adaptability, and scalability as opposed to adopting only one of them.

3.1 Hybrid Learning Frameworks

Hybrid AI systems are able to use the advantages of multiple learning paradigms. The structured prediction tasks, including classification and regression, are usually performed using supervised learning models, whereas unstructured data, including images, signals, and text, are processed by deep learning structures. Generative models are complimentary methods since they allow augmenting data, simulating and generating scenarios. This is possible due to hybridization, which enables systems to generalize more as conditions of operation vary, and also decreases the reliance on mass amounts of labeled data.

3.2 AI Pipelines for Risk-Aware Decision-Making

Decision-making systems within fields like finance and healthcare have to be subject to uncertainties and risk. The typical system of integrated AI pipelines consists of anomaly detection modules and predictive and generative elements to evaluate the system behavior in both normal and abnormal conditions. As an example, generative simulators have been developed to generate artificial stress events in order to gauge the resilience of a system to infrequent or extreme events, whereas models that detect anomalies are needed (Ghori, 2018; Puchakayala, 2024). This layered architecture is more reliable and can be proactively managed with respect to risk management.

3.3 Adaptive and Scalable Architectures

Scalability is an urgent need of AI systems that are used in large scale applications like with IoT networks and cyber-physical systems. At the edge-cloud type of the integrated architecture, lightweight models are run at the edge to provide real-time inference and more sophisticated models are run on centralized or cloud-based modules. Through such designs, adaptive learning and continuous updating of models are achieved and easier use of computational resources used.

4. Ethical, Interpretability, and Governance Challenges

The increased use of AI systems in sensitive and high-impact areas has increased the underlying concern regarding the issue of ethics, transparency, and governance. Due to the growing role of AI-driven decisions in determining financial results, diagnostics in healthcare, and services provided to the population, trust and accountability have become a research and policy priority.

4.1 Bias, Fairness, and Accountability

It is possible that machine learning models will reproduce prejudices of the training sets and can result in discrimination or unfairness. To resolve bias, one should pay attention to curating datasets, learning algorithms that are sensitivity to fairness and performance auditing. The mechanisms of accountability are also imperative to make it possible to trace the responsibility of the AI-driven decisions and prove them.

4.2 Interpretability and Explainable AI

A high number of successful AI models, most especially the deep neural networks, serve as black boxes, which is why it is hard to determine the method of obtaining decisions. The solution to this that explainable AI (XAI) methods attempt to offer is a model behavior explanation that consumers can comprehend. They are particularly important in the regulated realm where interpretable models are necessary, as the stakeholders have to explain decisions to the users, auditors, and regulators (Puchakayala, 2022).

4.3 Privacy, Security, and Robustness

The use of AI systems can be associated with issues of privacy and data security because these systems usually deal with the sensitive personal and institutional data. Such methods as data anonymization, differential privacy, and federated learning are becoming increasingly discussed in order to address the risk to privacy. Also, the AI models are prone to adversarial attacks, data poisoning as well as model inversion threats. Strong AI architectures should thus have security sensitive designs and constant monitoring in place so as to identify and curb such threats.

5. Emerging Trends and Research Opportunities

The AI research community is still growing at a fast pace due to development in computer infrastructure, data access and development of better algorithms. There are a number of emerging trends that will influence the future of intelligent decision-making systems.

5.1 Convergence of AI, IoT, and Cyber-Physical Systems

The combination of AI and IoT and Cyber-physical systems make contextually aware decisions in which recommendations are made based on real-time sensor and environmental feedback. This merger promotes smart transportation, healthcare surveillance, and smart infrastructure management.

5.2 Generative and Multimodal AI Systems

Multimedia is extending the capabilities of AI systems beyond prediction with the help of generative AI and multimodal learning. Multimodal models can give a more powerful contextual information as well as better resilience because they combine data in a very variety of modalities, including text, pictures, cues, and sensor data. These systems are further improved with the help of generative models making it possible to simulate, augment the data and create knowledge.

5.3 Toward Autonomous and Self-Learning Systems

It is predicted that the future AI systems will have advanced levels of autonomy with self-adjustment, lifelong learning, and low levels of human interaction. Academic research has the potential to develop systems to enable AI computing to improve through time, remain safe, reliable, and ethically sound.

6. Conclusion and Future Scope

This review provided a thorough analysis of the methods of artificial intelligence and machine learning that helps make intelligent decisions in the contemporary fields of computation. The paper has identified the progress made in the financial analytics field, healthcare, intelligent transportation, and IoT-enabled systems, and signal processing to emphasize that the use of data in predictive modeling, automation, and adaptive intelligence has changed. Combined AI systems, generative networks, and multimodal learning systems have become areas of inspiration towards strong and scaled intelligent systems. Simultaneously, the issues of interpretability, ethical guidelines, privacy, and security are especially problematic obstacles on the way to the large-scale and conscientious implementation.

The continuation of intelligent AI systems in the future study has taken the following directions:

- ***Development of Explainable and Transparent Models:*** Promoting interpretable AI for high-stakes systems
- such that the methods utilized to reach performance/interpretability balances.
- ***Ethically Governed AI Frameworks:*** Determining identical models of governance that deal with prejudices, responsibility, and regulatory conformity.
- ***Unified Multimodal Architectures:*** The development of scalable frameworks that can merge heterogeneous data modalities on a real time basis.
- ***Generative AI for Simulation and Robustness:*** Applicability Generative models training can be used to simulate uncommon occurrences to increase the diversity of data and to make systems more resilient.
- ***Edge-Cloud Collaborative Intelligence:*** Investigating adaptive AI systems which are capable of efficiently scattering computation over edge and cloud ecosystems.
- ***Continuous and Lifelong Learning Systems:*** Helping AI models to be constantly updated with changing streams of data, without forgetting in a disastrous way.

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