

Emerging Trends and Innovations in Artificial Intelligence and Data Science Technologies



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ABSTRACT

Artificial Intelligence (AI) and Data Science are revolutionizing industries by enabling transformative innovations and reshaping traditional processes and emerging trends such as Generative AI, Ethical AI, Federated Learning, and advancements in Natural Language Processing (NLP). It further explores innovations in real-time analytics, DataOps, and IoT integration, emphasizing their impact across diverse sectors, including healthcare, finance, retail, and climate science. These advancements present significant opportunities for enhancing efficiency, sustainability, and decision-making. Additionally, this article addresses critical challenges, including data privacy, ethical considerations, and the need for robust regulatory frameworks and proposed research directions aimed at fostering responsible, inclusive, and future-ready technological advancements.

Keywords: Artificial Intelligence, Data Science, Generative AI, Ethical AI, Federated Learning, NLP, Real-time Analytics, Data Privacy

Introduction

Artificial Intelligence (AI) and Data Science have emerged as transformative forces, revolutionizing the way industries operate and fostering groundbreaking innovations across the globe. These technologies have become integral to solving complex problems, optimizing processes, and driving informed decision-making across diverse fields such as healthcare, finance, retail, and environmental science [1]. With the advent of advanced machine learning algorithms, real-time analytics, and IoT integration, AI and Data Science are redefining traditional workflows and opening new frontiers of opportunity. The rapid evolution of AI technologies, including Generative AI and advancements in Natural Language Processing (NLP), has pushed the boundaries of automation and human-computer interaction.

At the same time, Ethical AI and Federated Learning have emerged to address critical challenges related to fairness, privacy, and accountability, ensuring these innovations are both inclusive and responsible [2]. These emerging trends are reshaping industries by creating smarter, more adaptive systems capable of understanding and responding to complex, real-world scenarios. This paper delves into the latest developments in AI and Data Science, highlighting key trends and innovations while addressing the challenges of data security, ethical concerns, and regulatory frameworks [3]. It further explores the transformative impact of these technologies and outlines future directions for research, aiming to create sustainable, efficient, and equitable solutions that benefit society at large.

Emerging Trends in Artificial Intelligence

1. Generative AI

Generative AI models, such as GPT (Generative Pre-trained Transformer) and Stable Diffusion, are reshaping the landscape of artificial intelligence by unlocking unprecedented creative and functional possibilities [4]. These models are designed to generate new data, whether in the form of text, images, audio, or even videos, by learning from vast datasets. Their applications span across diverse fields, offering innovative solutions and redefining traditional workflows.

Applications: Generative AI is widely utilized in personalized virtual assistants that can deliver tailored responses based on user preferences, significantly enhancing user experience. In content creation, these models automate the production of high-quality written articles, advertisements, and visual designs,

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making creative industries more efficient and accessible. In education, generative AI powers adaptive learning tools, which cater to the unique needs of individual students, thereby promoting inclusive education.

Impact: The impact of generative AI extends to improving user engagement and accessibility, particularly in underserved regions. By offering cost-effective and scalable solutions, generative AI has the potential to bridge gaps in education, healthcare, and other critical areas [5]. For instance, text-to-speech models can assist visually impaired individuals, while automated content generation tools can enable small businesses to compete with larger enterprises.

2. Ethical and Responsible AI

As AI systems increasingly influence decision-making in critical domains such as healthcare, finance, and criminal justice, the importance of ethical AI cannot be overstated. Ethical and responsible AI frameworks focus on ensuring fairness, transparency, and accountability in AI models and applications.

Applications: Explainable AI (XAI) is emerging as a key component in building trust in AI systems. For example, in financial decision-making, XAI enables stakeholders to understand the reasoning behind credit approvals or risk assessments [6]. Similarly, unbiased hiring algorithms are being developed to reduce discriminatory practices in recruitment processes, ensuring that decisions are based on merit rather than unconscious biases.

Impact: Ethical AI enhances the trustworthiness of AI systems by addressing concerns related to bias, discrimination, and lack of transparency. It fosters compliance with global regulatory standards, such as the European Union's AI Act, and encourages responsible innovation. By aligning AI development with societal values, ethical AI ensures that technological advancements benefit all sections of society equitably.

3. Federated Learning and Edge AI

Federated learning and Edge AI are revolutionizing the way AI models are trained and deployed, emphasizing privacy, efficiency, and real-time decision-making. Federated learning enables decentralized training of AI models by leveraging data stored on multiple devices, thereby ensuring privacy and compliance with regulations like GDPR [7]. Edge AI, on the other hand, brings computational power closer to the data source, enabling real-time analytics and reducing dependency on centralized cloud systems.

Applications: Federated learning is being increasingly adopted in sectors such as healthcare, where patient data needs to remain private. For instance, hospitals can collaboratively train diagnostic models without sharing sensitive patient information [8]. Edge AI finds applications in autonomous vehicles, where real-time decision-making is critical for safety. IoT devices also leverage Edge AI for tasks such as predictive maintenance, energy optimization, and security surveillance.

Impact: These technologies enhance operational efficiency by minimizing latency, reducing data transmission costs, and ensuring data security. Federated learning empowers industries to derive actionable insights while maintaining data privacy, whereas Edge AI enables instant decision-making in time-sensitive environments.

Together, they are driving the next wave of AI innovations across various sectors.

4. Advancements in NLP

Natural Language Processing (NLP) has undergone remarkable advancements, enabling machines to understand, interpret, and generate human-like text with unprecedented accuracy. State-of-the-art models such as GPT and BERT have revolutionized language processing tasks, opening new possibilities in automation and communication.

Applications: NLP is extensively used in AI-powered chatbots, which provide instant customer support across industries, reducing wait times and improving customer satisfaction. Automated summarization tools are helping professionals in academia and business by distilling large volumes of information into concise formats [9]. In social media analytics, sentiment evaluation powered by NLP allows organizations to gauge public opinion and refine their marketing strategies.

Impact: By reducing operational costs and improving customer engagement, NLP technologies are transforming the way organizations interact with their stakeholders. They facilitate multilingual communication, breaking down language barriers and promoting global collaboration. In addition, NLP tools are aiding researchers and policymakers in analyzing trends and sentiments to make informed decisions.

5. AI for Automation

Automation driven by AI is reshaping industries by optimizing operations, reducing human intervention in repetitive tasks, and improving overall efficiency. From manufacturing to agriculture, AI-powered systems are enabling organizations to achieve new levels of productivity.

Applications: In manufacturing, AI-driven robotics are performing tasks such as assembly line operations, quality control, and predictive maintenance. Logistics companies are using machine learning models to optimize supply chains, forecast demand, and enhance delivery routes [10]. In agriculture, precision farming technologies powered by AI are automating irrigation, monitoring crop health, and optimizing resource utilization.

Impact: AI for automation not only increases productivity and reduces costs but also addresses global challenges such as food security and resource conservation. By streamlining operations and minimizing errors, AI-driven automation is creating more resilient supply chains and contributing to sustainable development.

Innovations in Data Science Technologies

1. DataOps and MLOps Practices

The integration of DataOps (Data Operations) and MLOps (Machine Learning Operations) is reshaping the way organizations manage the lifecycle of data and machine learning models. These practices are designed to streamline collaboration between data engineers, scientists, and IT teams, enabling the efficient deployment, monitoring, and management of data pipelines and machine learning workflows [11]. By incorporating automation, continuous integration, and deployment strategies, DataOps and MLOps ensure that insights and predictions are both accurate and actionable.

Applications: In financial services, these practices are instrumental in real-time fraud detection. By continuously monitoring transactional data, organizations can identify anomalies and suspicious activities with high precision [12]. Similarly, in supply chain management, predictive analytics powered by DataOps and MLOps helps in forecasting demand, optimizing inventory, and reducing operational costs.

Impact: The adoption of DataOps and MLOps significantly improves the accuracy, reliability, and scalability of data-driven insights across industries. These practices reduce the time to market for machine learning models and enhance the agility of organizations, allowing them to respond swiftly to changing market conditions. Furthermore, they ensure compliance with regulatory standards by maintaining data integrity and traceability throughout the lifecycle.

2. Real-time Analytics

Real-time analytics has emerged as a cornerstone of modern decision-making, empowering organizations to process and analyze data as it is generated [13]. This capability allows businesses to respond instantly to dynamic conditions, enabling proactive strategies and minimizing risks in critical situations.

Applications: In the stock market, real-time analytics platforms analyze fluctuating stock prices, market trends, and investor sentiment, enabling traders to make informed decisions within seconds. In healthcare, patient monitoring systems use real-time analytics to track vital signs and alert medical personnel to potential emergencies, improving patient outcomes [14]. Real-time fraud detection systems, particularly in e-commerce and banking, analyze transactional data to prevent fraudulent activities before they occur.

Impact: Real-time analytics enhances the speed and quality of decision-making, providing organizations with a competitive edge in fast-paced industries. It also improves operational efficiency by identifying and addressing issues as they arise, reducing downtime and associated costs [15]. Furthermore, the ability to process high-velocity data streams in real-time drives innovation in sectors such as telecommunications, transportation, and emergency management.

3. Integration with IoT

The convergence of Data Science with the Internet of Things (IoT) has paved the way for smarter, more connected ecosystems. By leveraging data generated from IoT devices, organizations can derive actionable insights that enhance operational efficiency and promote sustainability [16]. This integration has applications across a wide range of domains, from smart cities to industrial automation.

Applications: In energy management, IoT-enabled smart grids use data science to optimize energy distribution and reduce wastage, contributing to sustainability goals. Predictive maintenance systems in manufacturing analyze data from IoT sensors embedded in machinery to forecast potential failures, minimizing downtime and maintenance costs. In smart cities, data from IoT devices is used to optimize traffic flow, reduce energy consumption, and improve public services.

Impact: The integration of IoT and data science transforms traditional systems into intelligent ecosystems, enabling real-time decision-making and resource optimization.

It also facilitates the development of sustainable solutions, such as reducing carbon footprints through energy-efficient operations.

4. Advances in Data Visualization

Data visualization has evolved beyond static charts and graphs to include interactive and immersive tools that allow stakeholders to explore complex datasets intuitively. Advanced visualization technologies enable users to identify patterns, trends, and anomalies, making analytics more accessible to non-technical audiences.

Applications: In business intelligence, interactive dashboards provide executives with real-time insights into key performance indicators, enabling data-driven decision-making. Scientific research leverages advanced visualization tools to analyze large datasets, such as genomic data or climate models, uncovering insights that would be difficult to discern otherwise [17]. Public health management uses data visualization to monitor disease outbreaks, track vaccination rates, and communicate findings effectively to policymakers and the public.

Impact: By presenting data in visually engaging and intuitive formats, advanced visualization tools bridge the gap between complex analytics and actionable insights. These tools democratize access to data by enabling stakeholders at all levels to make informed decisions. Additionally, they foster collaboration by providing a shared understanding of data, which is particularly critical in interdisciplinary projects and global initiatives.

Applications Across Industries

1. Healthcare

Artificial Intelligence (AI) and Data Science are revolutionizing healthcare by providing innovative solutions that enhance diagnostic accuracy, streamline treatment processes, and improve patient care outcomes. Advanced AI models analyze medical imaging with unparalleled precision, detecting conditions such as cancer and cardiovascular diseases at early stages [18]. Personalized medicine, powered by genomic data analytics, allows for treatments tailored to individual patients' needs. Predictive analytics helps in identifying potential outbreaks and managing hospital resources more efficiently.

Examples: AI-powered imaging tools like DeepMind's health projects assist radiologists in identifying abnormalities in scans. Drug discovery platforms use machine learning to expedite the identification of promising compounds, reducing development timelines and costs.

Impact: These technologies improve patient outcomes by enabling faster, more accurate diagnoses and personalized treatments. Moreover, they reduce healthcare costs by minimizing unnecessary tests and hospital readmissions, fostering a more efficient healthcare ecosystem.

2. Finance

The finance sector has embraced AI and Data Science to enhance operational efficiency, reduce risks, and deliver personalized experiences to customers. Fraud detection systems analyze transactional data in real-time to identify and prevent unauthorized activities. Automated trading algorithms leverage market data to execute high-frequency trades with precision [19].

Personalized financial advice, powered by AI, helps customers make informed decisions about investments and savings.

Examples: AI-enabled robo-advisors like Betterment and Wealthfront provide tailored investment strategies. Credit scoring models use machine learning to assess borrower risk more accurately than traditional methods.

Impact: These innovations reduce financial risks by detecting fraudulent activities and improving credit evaluation processes. They also enhance customer satisfaction by offering personalized solutions and optimizing financial services, driving greater trust and adoption.

3. Retail and E-commerce

AI and Data Science are transforming the retail and e-commerce landscape by enabling businesses to offer personalized shopping experiences and optimize their operations. Recommendation systems analyze customer behavior and preferences to suggest products, increasing engagement and sales [20-25]. Demand forecasting models help businesses anticipate inventory needs, reducing stockouts and overstocking.

Examples: Dynamic pricing algorithms adjust product prices in real-time based on market trends and customer demand. AI-driven inventory management systems optimize warehouse operations and streamline supply chains.

Impact: These technologies enhance profitability by improving customer satisfaction and operational efficiency. They also reduce waste and promote sustainability by aligning inventory with actual demand, minimizing excess production.

4. Climate Science

AI and Data Science are playing a pivotal role in tackling climate change and promoting sustainability. Predictive models analyze climate data to forecast extreme weather events, helping communities prepare and mitigate risks [17]. Data-driven urban planning tools optimize resource utilization in cities, reducing energy consumption and emissions.

Examples: Renewable energy optimization systems maximize the efficiency of solar and wind power generation. AI-driven simulations assist in designing sustainable urban environments and transportation networks.

Impact: These technologies drive sustainability by improving resource efficiency and enabling proactive measures against climate challenges. They also foster innovation in renewable energy and conservation efforts, contributing to a more sustainable future.

Challenges and Ethical Considerations

1. Data Privacy: The increasing reliance on big data raises significant concerns about the security and privacy of sensitive information. Ensuring robust encryption, secure storage, and compliance with data protection regulations, such as GDPR, is critical.

2. Bias in Algorithms: AI systems often reflect biases present in the data they are trained on, leading to discriminatory outcomes. Addressing these biases through diverse datasets, regular audits, and fairness-aware algorithms is essential for equitable AI applications.

3. Regulatory Frameworks: The absence of standardized global regulations for AI development and deployment creates challenges in ensuring ethical practices. Establishing frameworks that promote transparency, accountability, and inclusivity is vital to the responsible use of AI.

Future Directions and Research Opportunities

1. Quantum AI: The integration of quantum computing with AI promises unprecedented computational power, enabling the resolution of complex problems that are currently intractable. Potential applications include drug discovery, cryptography, and optimization problems in logistics and finance.

2. AI for Sustainability: AI's role in combating climate change is expanding, with applications in renewable energy management, precision agriculture, and waste reduction. Research is focused on developing AI tools that enhance the efficiency and scalability of sustainability initiatives.

3. Collaborative Research: Strengthening collaboration between academia and industry is crucial for bridging the gap between theoretical advancements and practical implementations. Interdisciplinary partnerships can accelerate innovation and ensure that AI technologies address real-world challenges effectively.

Conclusion

The rapid advancements in AI and Data Science technologies are driving transformative innovation across industries, from healthcare and finance to retail and climate science. While challenges such as data privacy, algorithmic bias, and regulatory gaps persist, addressing these issues through ethical practices and collaborative efforts will unlock the full potential of these technologies. By fostering inclusivity, sustainability, and interdisciplinary collaboration, the future of AI and Data Science holds the promise of significant societal impact. Embracing these innovations responsibly will enable us to create a more equitable, efficient, and sustainable world.

Table 1: Overview of Emerging Trends and Innovations in AI and Data Science

Trend/Innovation	Description	Applications	Impact
Generative AI	AI models that can generate new content (e.g., text, images, music).	Personalized virtual assistants, dynamic content generation, education.	Enhances creativity, improves engagement, and fosters accessibility.
Ethical and Responsible AI	Emphasis on fairness, transparency, and accountability in AI development.	Explainable AI in finance, unbiased hiring algorithms.	Builds trust, ensures compliance with regulations, reduces biases.
Federated Learning & Edge AI	Decentralized model training with enhanced privacy and real-time analytics.	Healthcare data sharing, autonomous vehicles, IoT devices.	Protects user data, improves real-time decision-making, reduces latency.
Advancements in NLP	Innovations in machine understanding and generation of human language.	AI-powered chatbots, sentiment analysis, social media analytics.	Improves customer engagement, automates tasks, enhances accessibility.
AI for Automation	Automation of tasks using AI to increase productivity and efficiency.	Precision agriculture, predictive maintenance, smart warehouses.	Increases operational efficiency, reduces costs, supports scalability.
DataOps and MLOps	Practices for efficient deployment and real-time monitoring of data and ML.	Fraud detection, predictive analytics in business operations.	Improves accuracy, reliability, and operational performance.
Real-time Analytics	Platforms enabling immediate data processing and decision-making.	Stock market analysis, real-time fraud detection, patient monitoring.	Enhances decision-making speed and precision in critical situations.
Integration with IoT	Combining data science with IoT for smarter ecosystems.	Energy optimization in smart grids, predictive maintenance in industries.	Promotes sustainability, optimizes resources, reduces inefficiencies.
Data Visualization	Tools that allow users to easily interpret complex data.	Business intelligence dashboards, scientific research.	Enhances data understanding, improves decision-making for stakeholders.
AI in Healthcare	AI-driven tools for personalized treatment and diagnostics.	Imaging tools, drug discovery platforms, patient monitoring.	Improves patient outcomes, reduces healthcare costs, enhances diagnosis.

Table 2: Applications of AI and Data Science Across Industries

Industry	AI/Data Science Applications	Examples	Impact
Healthcare	AI-driven diagnostics, personalized treatments, predictive analytics.	AI-powered imaging tools, drug discovery platforms.	Improved patient care, faster diagnoses, cost reduction.
Finance	Fraud detection, automated trading, personalized financial advice.	Robo-advisors, AI-based credit scoring models.	Enhanced customer experience, reduced financial risk.
Retail & E-commerce	Personalized recommendations, demand forecasting, AI-driven inventory.	Dynamic pricing algorithms, inventory optimization systems.	Increased profitability, reduced waste, improved customer satisfaction.
Climate Science	AI-based predictive models, renewable energy optimization, sustainability.	Climate change forecasting, energy grid optimization.	Supports sustainability, addresses climate change, reduces energy waste.

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