

Charting the Path Forward: An In-Depth Analysis of Breakthroughs and Hurdles in Artificial Intelligence

Mohd. Wasiullah¹, Piyush Yadav^{2*}, Ankit Yadav³

Abstract

Recent years have witnessed tremendous progress in artificial intelligence (AI), fueled by exponential increases in processing power and data accessibility. These developments have made it possible for AI to be widely used in a variety of industries, such as healthcare, finance, autonomous driving, and more. Significant difficulties are presented by the "black-box" nature of many AI systems, which lack transparency and the capacity to explain. By encouraging algorithms that can display their internal workings and decision-making, Explainable AI (XAI) seeks to address this. Notwithstanding notable advancements, issues like security, evaluation techniques, and the trade-off between performance and explainability still exist. The potential and limitations of AI technologies are highlighted in this review, which examines the most recent advancements in the field with an emphasis on approaches, applications, and the continuous attempts to overcome these obstacles. AI has quickly emerged as a revolutionary force, influencing many areas of our daily routines, including the way we interact, work, and live. This thorough analysis explores the notable developments and enduring difficulties in AI, providing a fair assessment of both its enormous potential and intrinsic complexity. Benefit: AI has advanced remarkably in recent years, especially thanks to advancements in deep learning and machine learning. These developments allow AI systems to process large volumes of data, identify complex patterns, and make highly precise judgments. Applications of AI are found in a wide range of industries, including healthcare, where it helps with early disease detection and individualized treatment plans, and finance, where it improves risk management and fraud detection. AI has made notable advancements in transportation, with key examples including autonomous vehicles and smart traffic management systems. AI-powered personalized learning experiences have revolutionized education as well.

Keyword: Artificial Intelligence (AI), machine learning (ML), deep learning (DL), neural networks, natural language processing (NLP)

INTRODUCTION

Artificial intelligence (AI) has rapidly become a transformative influence, reshaping various aspects of our daily lives, such as our interactions, work routines, and lifestyles. This comprehensive review delves into the significant advancements and persistent challenges within AI, offering a balanced perspective on its vast potential and inherent complexities.

Advantages: Recent years have witnessed remarkable progress in AI, particularly through innovations in machine learning (ML) and deep learning (DL) [1]. These developments allow AI systems to analyze large volumes of data, identify complex patterns, and make precise decisions [2]. AI applications span numerous fields: from healthcare, where AI assists in early disease

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detection and personalized treatment plans, to finance, where it enhances fraud detection and risk management. In the field of transportation, AI has made significant contributions through autonomous vehicles and advanced traffic management systems. Education has also been transformed with personalized learning experiences driven by AI technologies [3].

Challenges: Despite these significant advancements, AI faces several critical challenges. The "black-box" characteristic of numerous AI models poses a major issue, as it obscures their decision-making processes and creates concerns about accountability and transparency [4]. Unfair and discriminatory results can result from biases in AI systems, which frequently originate from training data. Additionally, creating and deploying AI systems is expensive and demands large amounts of high-quality data [5]. Ensuring the privacy and security of this data is an ongoing concern, alongside the need for ethical frameworks to guide AI's responsible deployment [6].

ENSURING THE ETHICAL USE OF ARTIFICIAL INTELLIGENCE

As AI technologies continue to play a larger role in our daily lives and society, ensuring their ethical use is crucial [7]. Ensuring that AI systems are designed and deployed ethically involves addressing several critical factors, including transparency, accountability, fairness, and privacy [8].

Transparency

The openness and clarity with which AI systems function is referred to as transparency in AI. One way to accomplish this is by making AI algorithms and their decision-making processes understandable to humans [9]. Explainable AI (XAI) is a field dedicated to creating AI systems whose actions can be easily interpreted, ensuring that users and stakeholders can trust and understand the decisions made by these systems [10–15].

Accountability

This entails making AI operators and developers answerable for the results produced by AI systems [15–20]. This entails creating precise rules and specifications for AI development, putting strong testing and validation procedures in place, and making sure that procedures are in place to deal with any damage or unforeseen outcomes brought on by AI applications [21–25].

Fairness

Making sure AI systems do not reinforce or worsen prejudices and inequalities is the goal of fairness. Identifying and minimizing biases in AI algorithms and datasets requires comprehensive testing. Furthermore, in order to prevent discrimination and guarantee that all users are treated fairly, AI systems should be developed to encourage inclusivity and fairness across various demographic groups [25–28].

Privacy

Protecting user privacy is a fundamental aspect of ethical AI systems frequently use vast volumes of data, including private data, which needs to be managed carefully. This entails putting in place robust data protection measures, making sure that data privacy laws are followed, and being open and honest about the ways in which data is gathered, used, and stored [29, 30].

Ethical Frameworks and Governance

Establishing ethical frameworks and governance structures is crucial for guiding the development and deployment of AI. Diverse stakeholders, including ethicists, technologists, legislators, and the general public, should contribute to these frameworks. They ought to offer standards for moral AI behavior, encourage constant observation and assessment, and guarantee that AI systems conform to social norms and values.

ARTIFICIAL INTELLIGENCE CHALLENGES

Although AI has the potential to completely transform industries, there are a number of obstacles that it must overcome. Here are a few of the main obstacles:

- Bias and ethics biases in training data may be unintentionally reinforced or even made worse by AI systems.

- Ensuring fairness and mitigating biases requires rigorous testing and evaluation.
- Many AI models, particularly deep learning models, operate as "black boxes," making their decision-making processes hard to interpret and understand. Gaining trust and guaranteeing accountability require improving transparency and developing explainable AI (XAI).
- The use of vast amounts of personal data by AI often leads to concerns about data security and privacy. Ensuring the protection of this data and compliance with data protection regulations is essential. The ability to generalize and be robust It can be difficult for AI systems to extrapolate from their training data to novel, untested scenarios. It is still difficult to create models that are reliable and flexible enough to work in a range of situations.
- Resources for computation: Significant computational resources are needed to train sophisticated AI models, which can be costly and harmful to the environment. Hardware innovations and effective algorithms are needed.
- Ensuring that AI systems are developed and used responsibly requires robust governance and regulation that keeps pace with technological advancements.

Ethical Use: Determining the ethical boundaries of AI applications, particularly in sensitive areas like surveillance and autonomous weapons, poses a significant challenge. Responsible AI deployment requires the establishment of ethical frameworks and guidelines.

- There is a shortage of skilled professionals due to the high demand for qualified AI experts surpassing the available talent. Investing in education and training is crucial to building a workforce capable of developing and managing AI technologies.
- Integration and Compatibility: Integrating AI into existing systems and ensuring compatibility with current technologies can be complex and costly. Effective integration strategies are necessary to maximize AI's benefits.
- Impact on the Economy and Society: AI has the power to upend economic systems and labor markets, which could result in inequality and job displacement. Careful policymaking and proactive steps to assist impacted workers are necessary to address these socioeconomic effects.

ARTIFICIAL INTELLIGENCE AND ITS SUBFIELDS

AI is a large field with a number of subfields, each of which focuses on a distinct facet of intelligent behavior and judgment. Here is an overview of several key subfields within AI:

- *Machine Learning (ML):* ML is the study of statistical models and algorithms that allow computers to carry out particular tasks without direct instructions by using inference and patterns. Reinforcement learning, supervised learning, and unsupervised learning are key techniques in machine learning.
- *Deep Learning (DL):* DL is a subset of machine learning that concentrates on neural networks with multiple layers, also known as deep neural networks. Large data processing is a strength of these models, especially when it comes to image and speech recognition tasks.
- *Natural Language Processing (NLP):* NLP is a technology that allows computers to interact with human language, enabling machines to interpret, comprehend, and produce text. It is used in various applications like chatbots, translation services, and sentiment analysis.
- *Computer Vision:* This area of study focuses on how computers can interpret digital images or videos in a sophisticated manner. It covers tasks including object detection, image production, and image recognition.
- *Robotics:* Robotics integrates AI with mechanical engineering to design and construct robots. These robots are capable of a wide range of jobs, from basic manufacturing to more complicated operations like autonomous driving or surgery.
- *Expert Systems:* These are AI algorithms that simulate a human expert's decision-making process. They tackle complicated issues in particular fields, such as financial forecasting or medical diagnostics, using a set of facts and rules.

- *Reinforcement Learning (RL)*: This kind of machine learning involves teaching agents to make choices by acting in a way that maximizes the total reward in the environment. Autonomous vehicles, gaming, and robots all make extensive use of it.
- *Speech Recognition*: This subfield is dedicated to transforming spoken language into written text. Applications for it include accessibility tools, transcribing services, and virtual assistants.
- *Autonomous Systems*: These systems are capable of carrying out activities without assistance from humans. Drones, industrial automation systems, and self-driving automobiles are a few examples.
- *Knowledge Representation and Reasoning*: This field focuses on providing knowledge about the outside world in a way that a computer system can use to accomplish difficult tasks like conversing or detecting a medical issue.
- *Neural Networks*: These computing systems are inspired by the natural neural networks found in animal brains. A number of machine learning techniques, especially those used in deep learning, are based on these systems.
- *Fuzzy Logic*: This type of many-valued logic addresses imprecise reasoning as opposed to fixed and accurate reasoning. It is used in systems that must process uncertain or imprecise information.

SUBSETS OF ARTIFICIAL INTELLIGENCE

Subsets of AI are shown in Figure 1.

FUTURE REGULATION

AI regulation is expected to be dynamic and multidimensional in the future, tackling legal, ethical, and technological issues. Strong regulatory frameworks will be necessary as AI continues to permeate many industries to guarantee that its development and application are consistent with public trust and social values¹. Transparency, accountability, equity, and privacy are major areas of emphasis, and there are international initiatives to create thorough rules and regulations. Promoting innovation while reducing risks and guaranteeing that everyone benefits equally is the aim.

ARTIFICIAL INTELLIGENCE TOOLS AND SERVICES

AI tools and services have become indispensable across various industries, offering powerful capabilities to enhance productivity, decision-making, and innovation.

Artificial Intelligence Tools

- *Tensor Flow*: An open-source framework developed by Google for applications involving DL and ML.
- *PyTorch*: Facebook created this open-source machine learning package, which is renowned for its adaptability and dynamic computing graph.

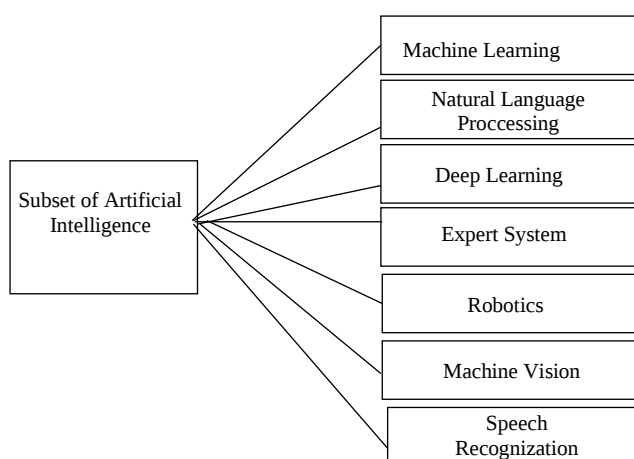


Figure 1. Subsets of artificial intelligence.

- *Sickest-Learn*: A Python library offering user-friendly and efficient tools for data mining and analysis.
- *Keras*: A Python-based high-level neural network API that may be used with Tensor Flow, CNTK, or Theano. OpenAI GPT is an advanced language model designed to produce text that mimics human writing, applicable to a wide range of natural language processing tasks.
- *IBM Watson*: A collection of AI services that includes machine learning, language comprehension, and data analytics powered by AI.
- *Azure Machine Learning*: Microsoft's cloud platform for developing, refining, and deploying machine learning models.
- *Google Cloud AI*: Provides a stable environment for developing custom machine learning models in addition to pre-trained models.
- *AI Services*: It includes Amazon Recognition, which makes it simple to incorporate video and image analysis into apps.
- *Azure Cognitive Services*: A collection of Microsoft tools and APIs for AI in areas such as speech, language, vision, and decision-making.
- *IBM Watson Assistant*: A virtual agent service that provides conversational interfaces across various channels.
- *Google Cloud AI*: Provides machine learning tools and APIs for predictive analytics, computer vision, and natural language processing.
- *Dialog Flow*: Google's natural language comprehension platform for creating conversational user interfaces.
- *Sales Force Einstein*: An integrated set of AI technologies that bring advanced AI capabilities into the Sales Force platform.

ARTIFICIAL INTELLIGENCE TRANSFORMING THE WORLD

The world is changing dramatically due to artificial intelligence (AI), which is reshaping daily life and industries. AI is having a major impact in the following important areas: AI in healthcare improves individualized treatment regimens and medical diagnostics. AI systems can analyze vast amounts of medical data to detect patterns and predict disease progression with remarkable accuracy.

AI-powered tools assist in early detection of diseases, personalized medicine, and drug discovery, making healthcare more efficient and effective.

Finance

AI is applied in the financial sector for tasks such as automated trading, managing risks, and identifying fraudulent activities. AI algorithms forecast financial results and examine market trends, offering insightful information for investment plans. Virtual assistants and chatbots improve customer service by efficiently addressing frequently asked questions.

Transportation

AI is propelling the creation of driverless cars, which hold the promise of safer and more effective transportation. AI systems can optimize traffic flow, minimize human error, and navigate challenging environments. AI in logistics increases delivery efficiency and supply chain management.

Education

By tailoring instructional materials to each student's needs, AI personalizes learning experiences. Intelligent tutoring programs improve learning by offering immediate feedback and assistance. Moreover, AI assists in streamlining administrative tasks, allowing educators to focus more on teaching.

Entertainment

AI-powered content recommendation systems, like those employed by streaming services, are revolutionizing the entertainment industry. Like music and art, AI-generated content is growing in

popularity and pushing the limits of creativity. AI improves player experiences in gaming by producing responsive and adaptive game environments.

Agriculture

AI-powered technologies improve agricultural practices by optimizing crop management, predicting weather patterns, and monitoring soil health. Drones and sensors, combined with AI, enable precision farming, reducing waste and increasing yield.

Smart Cities

By optimizing energy use, enhancing public safety, and improving waste management, artificial intelligence helps create smart cities. AI-powered analytics aid in resource allocation and urban planning, improving the sustainability and livability of cities.

Customer Service

AI-driven chatbots and virtual assistants engage with customers by answering inquiries, recommending products, and assisting with problem-solving. This lowers operating expenses for companies while simultaneously improving customer satisfaction.

Manufacturing

AI improves supply chain efficiency, quality assurance, and predictive maintenance in manufacturing processes. Automation systems and robots driven by AI boost production efficiency and decrease the need for human labor in repetitive tasks.

Environment

AI aids in environmental conservation by analyzing climate data, predicting natural disasters, and monitoring wildlife populations. AI-driven technologies support sustainable practices and help mitigate the impacts of climate change.

IMPLEMENTING ARTIFICIAL INTELLIGENCE

Implementing AI involves identifying specific use cases, gathering and preparing data, selecting appropriate AI models, training and testing these models, and integrating them into existing systems

Application of Artificial Intelligence in Different Fields

AI has numerous applications across a wide range of fields, revolutionizing industries and enhancing various aspects of life (Figures 2 and 3). Here are some key applications:

Healthcare

- *Medical Diagnostics:* AI assists in analyzing medical images and diagnosing diseases like cancer and neurological disorders.

Finance

- *Fraud Detection:* AI identifies suspicious transactions and potential fraud.

Transportation

- *Autonomous Vehicles:* AI drives drones and self-driving cars, improving efficiency and safety.
- *Traffic Management:* By using intelligent traffic signals, AI maximizes traffic flow and lessens congestion.

Education

- *Personalized Learning:* AI enhances learning outcomes by tailoring instructional materials to each student's needs.
- *Administrative Automation:* AI handles administrative tasks, allowing teachers to focus more on teaching.

Retail

- AI examines customer behavior to offer tailored shopping experiences through customer insights.
- AI enhances inventory control by predicting demand and optimizing stock quantities.

Manufacturing

AI-powered predictive maintenance lowers maintenance expenses and downtime by anticipating equipment failures.

- *Quality control:* AI ensures high quality by checking products for flaws.
- AI-driven chatbots and virtual assistants address customer inquiries, recommend products, and assist with problem-solving. This lowers operating expenses for companies while simultaneously improving customer satisfaction.
- *Manufacturing:* AI improves supply chain efficiency, quality assurance, and predictive maintenance in manufacturing processes. Automation systems and robots driven by AI boost production efficiency and decrease the need for human labor in repetitive tasks.

Agriculture

- *Precision Farming:* AI optimizes planting, watering, and harvesting, improving crop yield and resource use.
- *Disease Detection:* AI identifies plant diseases early, allowing for timely intervention.

Entertainment

- *Content Suggestions:* AI makes recommendations for shows, movies, and music based on user tastes.
- *AI-Generated Content:* AI pushes the boundaries of creativity by producing stories, music, and artwork.

Energy

- *Grid Management:* AI maximizes energy use and distribution, cutting expenses and waste.
- *Renewable Energy:* AI forecasts weather patterns to increase wind and solar power's efficiency.

Security

- *Surveillance:* AI improves security measures by examining video feeds for odd activity.
- *Cybersecurity:* AI instantly recognizes and reacts to online threats.

Benefits/Advantages

Efficiency and Automation

- AI enhances productivity by handling dull and repetitive tasks, allowing humans to focus on more complex and creative endeavors. This leads to significant time and cost savings.

Enhanced Decision-Making

AI supports well-informed decision-making in industries like finance, healthcare, and logistics by analyzing massive datasets to find trends and insights that humans might overlook.

Personalization

AI provides personalized experiences in areas such as shopping, entertainment, and online services by analyzing user preferences and behaviors, leading to improved customer satisfaction.

Healthcare Advances

AI improves the overall quality of healthcare services by assisting with early disease detection, individualized treatment plans, and effective patient record management.



Figure 2. Applications of artificial intelligence (AI).

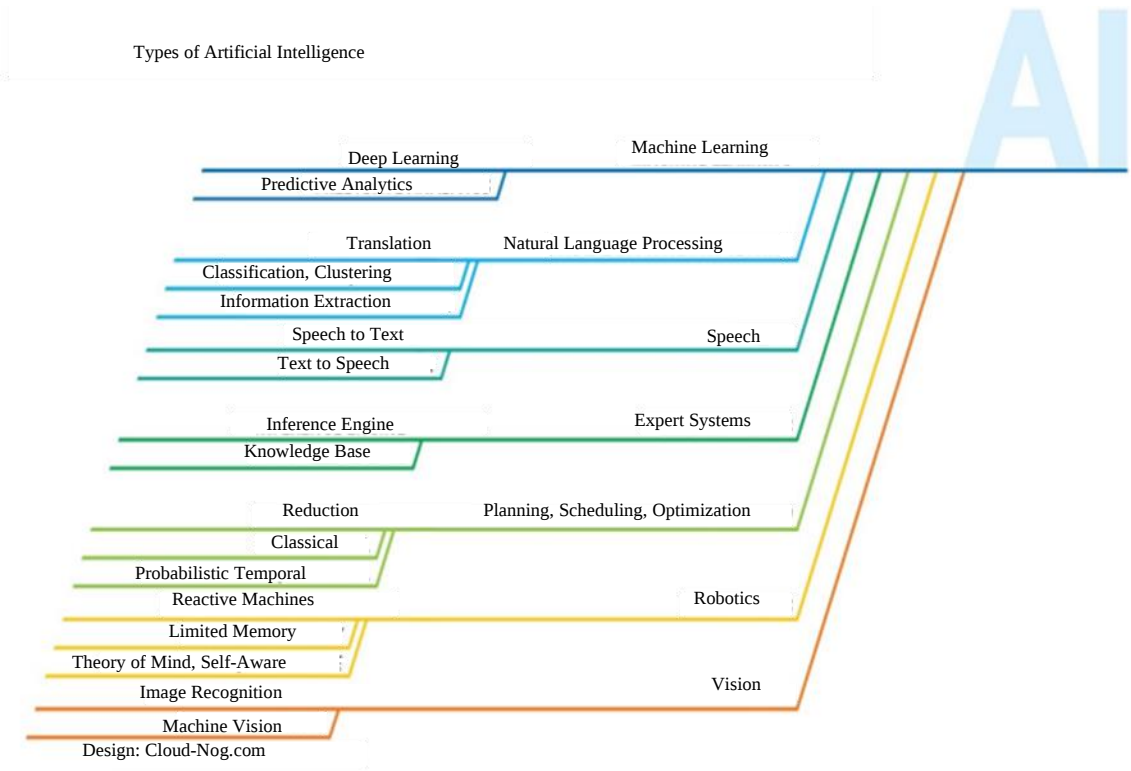


Figure 3. Types of artificial intelligence.

Safety and Security

AI-powered systems improve safety in various domains, from autonomous vehicles reducing traffic accidents to AI-enhanced surveillance systems bolstering security measures.

Predictive Analytics

AI models forecast trends and predict future outcomes in business, weather, and even healthcare, allowing for proactive measures and better planning.

Innovations in Education

AI personalizes learning experiences, provides intelligent tutoring systems, and automates administrative tasks, making education more accessible and effective.

Environmental Impact

AI optimizes resource use in agriculture and energy management, contributing to sustainability and environmental conservation efforts.

Enhanced Creativity

AI tools assist in creative fields like music, art, and literature by generating new ideas, compositions, and even entire artworks, pushing the boundaries of human creativity.

Improved Customer Service

AI chatbots and virtual assistants offer prompt answers to consumer questions, increasing customer satisfaction and service effectiveness.

Disadvantages/Risks

AI) has many advantages, there are some drawbacks and difficulties as well:

1. *Job Displacement:* AI has the potential to take over tasks, resulting in job losses and displacement across different sectors. This shift requires significant workforce retraining and adaptation.
2. *Bias and Discrimination:* Unfair and discriminatory results may result from AI systems that reinforce and even magnify preexisting biases in the data they are trained on.
3. *Lack of Transparency:* A lot of AI models, particularly deep learning algorithms, operate as "black boxes," making it challenging to decipher and comprehend how they make decisions. This raises questions about accountability and transparency.
4. *Privacy Issues:* AI frequently necessitates vast volumes of data, which presents serious privacy issues. Misuse of personal data and potential breaches can compromise individual privacy.
5. *Security Risks:* AI systems can be vulnerable to cyberattacks and manipulation, posing risks to security and safety, especially in critical applications like healthcare and autonomous vehicles.
6. *Dependency on Data Quality:* The performance of AI is heavily influenced by both the quantity and quality of the data. Inaccurate or detrimental results can result from poor or biased data.
7. *Ethical Dilemmas:* The application of AI in critical fields like surveillance, autonomous weaponry, and criminal justice decision-making brings up important ethical and moral dilemmas.

Artificial Intelligence in Marketing

By facilitating more individualized, effective, and data-driven strategies, AI is revolutionizing the marketing environment. Key uses of AI in marketing include the following:

1. *Customization:* AI leverages consumer data to tailor personalized experiences, suggestions, and content. By adapting messages to each customer's specific preferences and actions, marketers can boost engagement and drive higher conversion rates.
2. *Predictive Analytics:* By using AI models to forecast future consumer trends and behaviors, marketers can make well-informed choices regarding campaign tactics, inventory control, and new product launches. Marketing efforts can be optimized and high-value prospects can be found with predictive analytics.
3. *Customer Segmentation:* AI is capable of processing enormous volumes of data to divide consumers into discrete groups according to a range of factors, including preferences, demographics, and purchasing patterns. This makes more focused marketing possible.

4. *Content Creation*: Using preset parameters and data inputs, AI tools can produce content, including articles, social media posts, and email newsletters. This helps marketers maintain a consistent content schedule and frees up time for creative tasks.
5. *Chatbots and Virtual Assistants*: AI-driven chatbots and virtual assistants improve customer service and engagement by instantly responding to consumer questions. They are able to respond to standard inquiries, assist users with the purchasing process, and collect client feedback.
6. *Ad Targeting*: By examining user data, AI improves ad targeting by showing advertisements to the most pertinent audiences. This enhances the profitability of marketing campaigns and optimizes the effectiveness of advertising expenditures.
7. *Sentiment Analysis*: To determine how the general public feels about a brand or product, AI tools examine social media, reviews, and other online content. This helps marketers understand customer perceptions, manage brand reputation, and adjust strategies accordingly.
8. *Customer Relationship Management (CRM)*: By offering more profound insights into customer interactions and preferences, AI improves CRM systems. This enables more effective communication, personalized offers, and long-term relationship building.
9. *Visual Recognition*: Visual recognition tools with AI capabilities can identify products, brand logos, and even customer emotions by analyzing images and videos. This information aids marketers in comprehending the visual representation and perception of their brand.

CONCLUSION

As AI develops further, it has enormous potential to spur innovation and raise living standards everywhere. But in order to properly utilize this potential, the inherent problems of bias, transparency, privacy, and accessibility must be addressed. For AI technologies to be developed and applied in ways that serve the greater good, it is essential to have ethical guidelines and robust regulatory policies in place. We can create a future where AI is a force for good, promoting advancement and equity across a range of fields, by striking a balance between innovation, morality, and inclusive practices. The trajectory of AI is essentially one of limitless possibilities entwined with crucial responsibilities, emphasizing the necessity of a methodical and deliberate approach to its incorporation into our language.

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