# TECH REPORT:
# ARTIFICIAL INTELLIGENCE

IDB

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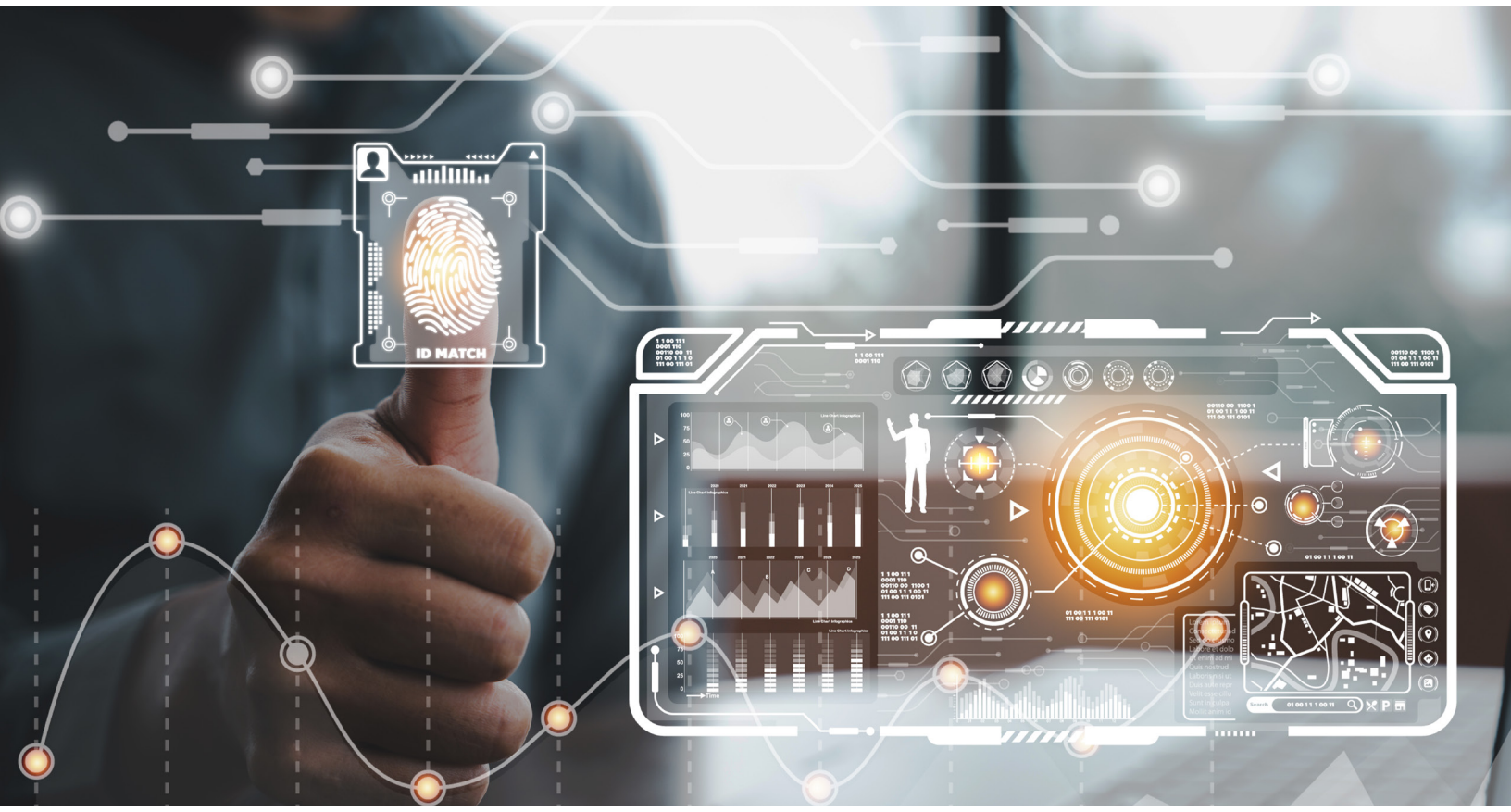
# TechLab

The TechReports are an initiative of the Emerging Technologies Laboratory of the IDB's IT department, known as TechLab, which is in charge of exploring, experimenting, and disseminating information about new technologies to learn about their impact on the IDB Group and the LAC region.

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# EXECUTIVE SUMMARY

**Artificial Intelligence (AI) has evolved significantly since its conception, and today it has a wide range of applications, transforming industries in profound ways.**

This report provides a comprehensive overview of AI, from its fundamentals to its practical applications, covering topics such as its definition, evolution, and implementation. It also delves into various applications, such as machine learning, natural language processing, computer vision, and generative AI, providing specific examples and use cases across sectors like healthcare, logistics, environment, and security.

The expanding influence of AI is reshaping everyday life and various industries. However, its responsible implementation requires a comprehensive understanding of its ethical and technical principles, as well as ongoing consideration of its impact on society and individual privacy. The report concludes with recommendations for responsible development and discussions on ethical concerns like privacy and transparency.

# DEFINITION

**Artificial Intelligence (AI)** is a complex field to define,[1] blending computer science with robust datasets to facilitate problem-solving[2]. Traditionally, it refers to the ability of digital computers or computer-controlled robots to perform tasks associated with intelligent beings[3].

Following Alan Turing's foundational work on what he called "mechanical intelligence," the term "artificial intelligence" was coined by computer scientist John McCarthy during the 1955 Dartmouth Conference and defined as:

> *"the science and engineering of making intelligent machines, especially intelligent computer programs. It is related to the similar task of using computers to understand human intelligence, but AI is not limited to methods that are biologically observable"*[6].

Over the years, AI has experienced numerous *hype cycles*[7] in all of its areas of study, but with the emergence of new models of mass-access generative AI in late 2022, such as ChatGPT, many of its discussions have regained momentum[8].

AI includes areas such as machine learning and deep learning, pattern recognition, decision-making, and natural language processing (NLP), among many others, aimed at solving diverse problems.

One central goal in AI research is the creation of General Artificial Intelligence (AGI), pursued by companies like OpenAI, DeepMind, and Anthropic. The timeline for AGI development is debated[9], with estimates ranging from years to decades, if not centuries, and some even questioning its feasibility. There's also controversy on whether modern large language models (LLM), like GPT-4, represent preliminary and incomplete forms of AGI. It is also a recurring theme in science fiction and future studies of the future of AI.

1. (Wang, 2019)
2. What is Artificial Intelligence (AI) ? | IBM
3. (Copeland, 2024)
4. (Turing, 1950)
5. (McCarthy et al., 2006)
6. (McCarthy, 2007)
7. Gartner Hype Cycle Research Methodology
8. (Inter-American Development Bank, 2023; Mollick, 2022)
9. (McLean et al., 2023)

# TRAINING TECHNIQUES AND APPLICATIONS

AI solutions are software programs and tools that use training techniques to perform specific tasks, ranging from simple and repetitive to complex cognitive functions that require human-like skills.

## DATA PROCESSING AND MACHINE LEARNING

**Machine Learning (ML)** mimics human learning processes, refining accuracy with each iteration. Essential to data science, ML employs statistical methods for algorithm training, prediction, and pattern discovery in data mining projects[10] .

El **aprendizaje profundo o *deep learning* (DL)** represents a subset of ML, employing artificial neural networks (ANN) with three or more layers to emulate human brain functions and "learn" from large amounts of data[11]. Although often conflated, DL differs from ML in its approach; DL can handle unstructured datasets without preprocessing, unlike ML that typically requires data preprocessing to exploit the structure and initial labeling of the information [12].

Both models stem from the analysis of large data volumes, known as **big data**, characterized by its volume, speed, and variety[13]. This refers to expansive collections[14] of structured, unstructured, and semi-structured data, continually growing over time[15].

**Reinforcement learning,** unlike supervised learning, does not require labeled examples or explicit correction of its mistakes. Instead, it balances exploration of new possibilities with leveraging existing knowledge, mimicking the human trial-and-error process to achieve goals[16].

**Predictive analytics and data mining** are related disciplines that focus on analyzing large datasets to extract valuable information and forecast future events. **Predictive analytics** uses statistical and ML techniques for trend prediction and future outcomes, while **data** mining uncovers hidden patterns in data for actionable insights. Both disciplines are critical to informed decision-making and process optimization in a variety of industries.

10. What is Machine Learning? | IBM
11. What is Deep Learning? | IBM
12. What is Machine Learning? | IBM
13. Big Data es otro concepto difícil de definir. (Favaretto et al., 2020)
14. Big Data Defined: Examples and Benefits | Google Cloud
15. Los datos estructurados son aquellos organizados en un formato predefinido y consistente, como tablas o bases de datos relacionales; los datos no estructurados carecen de un formato predefinido y no se pueden organizar fácilmente en una base de datos tradicional, como texto libre, imágenes o videos; y los datos semiestructurados tienen algún grado de estructura, pero no se ajustan completamente a un formato predefinido, como documentos XML o JSON.
16. https://aws.amazon.com/what-is/reinforcement-learning/

These applications are increasingly prevalent across diverse industries such as healthcare, finance, retail, and manufacturing. Here are some examples:

## Examples and Available Machine Learning Solutions

**Healthcare assistance.** Recent ML advancements in healthcare have lightened the load on doctors and enhanced care accuracy and quality. They aid in identifying trends, developing disease prediction models, and increasing the efficiency of medical institutions by organizing electronic records, detecting anomalies in specimens, and robotic-assisted surgeries[17].

**Motores de recomendación.** LDeep learning algorithms can analyze large collections of platform usage data to extract patterns and offer personalized recommendations. Examples include Netflix[18] or Spotify[19] recommendation algorithms, traffic predictions in Google Maps[20], and weather forecasts on The Weather Channel[21].

17. (Habehh & Gohel, 2021)
18. Research Areas: Machine Learning
19. Machine Learning - Spotify Research
20. Google Maps 101: How AI helps predict traffic and determine routes
21. IBM's The Weather Company Continues to Be the World's Most Accurate Forecaster Overall

**Autonomous driving.** Certain vehicles utilize neural networks and ML to detect obstacles and make real-time driving decisions based on sensor data like cameras and radars. Companies such as Waymo[22], Tesla[23] and Aurora[24] aim for fully autonomous driving capability, eventually.

**Financial fraud detection.** Predictive analytics algorithms analyze vast financial datasets to identify suspicious patterns and prevent potential fraud. Solutions are available from companies like IBM, Kount, FICO, and Feedzai[25].

**Manufacturing.** The manufacturing industry has been historically slow to adopt new technologies, and artificial intelligence is no exception[26]. However, with rapid advances in algorithms and more data available due to inexpensive sensors and smart manufacturing, the use of ML in manufacturing will grow quickly in applications such as predictive maintenance, warehouse management and quality improvement in complex processes such as semiconductor manufacturing[27].

# NATURAL LANGUAGE PROCESSING (NLP) AND COMMUNICATIONS

**Natural Language Processing (NLP)** is a field that combines computer science and linguistics and focuses on training computers to understand and work with human language.

It involves analyzing sets of text or speech data using rule-based or probabilistic machine learning methods to enable computers to comprehend the content and context of documents. Key challenges include recognizing and understanding the meaning of the linguistic components that make up a phrase or sentence, and generating natural language[28].

## Examples and Available NLP Solutions

**Virtual assistants.** Applications designed for conversational interactions[29], providing personalized advice. Examples include Siri (Apple), Assistant (Google), or Alexa (Amazon), along with custom-configured chatbots on platforms like Amazon Lex or Citibot[30].

**Speech recognition.** Enables computers to interpret and understand spoken human language, converting speech into text. It's used in virtual

22. AutoML: Automating the design of machine learning models for autonomous driving
23. Autopilot | Tesla
24. Aurora Innovation
25. (Abdallah et al., 2016)
26. (Stackpole, 2023)
27. (Wuest et al., 2016)
28. (Chowdhary, 2020)
29. (Inter-American Development Bank, 2023)
30. What is a Bot? - Types of Bots Explained - AWS

assistants and serves as an input method through dictation in operating systems, playing a crucial role in accessibility.

**Sentiment analysis on social media.** Social media data analysis predicts users' sentiment towards brands or products, for example, to evaluate their performance based on comments. Service providers include Brandwatch, Lexalytics, as well as IBM, and Microsoft.

29. (Inter-American Development Bank, 2023)
30. What is a Bot? - Types of Bots Explained - AWS

# COMPUTER VISION

**Computer vision** is the ability to automatically interpret and understand the visual world, using images, video, and deep learning models to accurately identify and classify objects[31].

Common engines include optical character recognition (OCR), intelligent character recognition (ICR)[32], and more advanced engines incorporate convolutional neural networks (CNN)[33].

## Examples and Available Computer Vision Solutions

**Biometric recognition.** Used to identify and authenticate individuals based on unique physical characteristics such as face, voice, or fingerprints. It's used in security systems like FaceID (Apple) and biometric payment systems, as well as social media filters and effects on platforms such as TikTok[35] and Instagram[36]. It is one of the most controversial AI implementations today[37], leading to several legislative initiatives worldwide[38].

31. What is Computer Vision? | IBM
32. A diferencia del OCR, ICR puede reconocer caracteres manuscritos y no solo impresos.
33. What is OCR? - Optical Character Recognition Explained - AWS
34. Usar Face ID en el iPhone o iPad Pro - Soporte técnico de Apple
35. Face Info | Learn | TikTok Effect House
36. Introducing Face Filters & More on Instagram | Instagram Blog
37. (Chokshi, 2019)
38. (Bu, 2021)

**Automated visual inspection.** Uses computer vision, ML, and CNN technologies to detect defects or anomalies and ensure process quality. Examples include Cognex[39], which focuses on industrial and manufacturing solutions, and NVIDIA, which covers various fields, including medical applications, with its Clara platform[40].

# GENERATIVE ARTIFICIAL INTELLIGENCE

**Generative AI (GenAI)**[41] utilizes ML to create new content based on a training dataset, capable of generating various forms such as text, images, videos, audio, code, or 3D renderings. It finds applications in enhancing customer interactions, querying large amounts of information, and automating repetitive tasks in businesses[43].


39. Cognex
40. NVIDIA Clara | AI-powered Solutions for Healthcare
41. https://publications.iadb.org/en/tech-report-generative-ai
42. Reporte IA Generative BID
43. ¿Qué es la IA generativa y cuáles son sus aplicaciones? Google Cloud

## Examples and Available Generative AI solutions

**Content generation.** The generation of images, text, audio, video, synthetic data and 3D models has applications in fields such as advertising and marketing, as well as healthcare, security, editing and design. The field has gained a great attention due to the popularity of applications such as OpenAI's ChatGPT[44], Microsoft's Copilot[45], and Google's Gemini (formerly Bard)[46].

**Assisted design.** Design tools, prototyping, logo creation, or visual art generation leverage GenAI for personalized results that are evaluated prior to production. For example, Autodesk utilizes AI in its solutions[47] to optimize design and prototype simulation, streamlining manufacturing processes. Adobe also incorporates AI into many of its products for design purposes[48].

**Process optimization.** GenAI aids in code generation, accelerating programming tasks and error detection. GitHub Copilot[49] and Google's Gemini[50] or Vertex AI[51] are examples that suggest code and provide assistance to developers.

44. ChatGPT
45. Microsoft Copilot
46. Gemini
47. Autodesk AI | Artificial Intelligence
48. Generative AI – Adobe Sensei
49. GitHub Copilot · Your AI pair programmer
50. Bard now helps you code
51. Generación de código con IA | Google Cloud

# ARTIFICIAL INTELLIGENCE USE CASES

37% of organizations have already implemented some form of AI, an increase of 270% in the last few years[52].

This growth is a testament to its importance, as the global AI software market is expected to reach approximately USD 126 billion in revenue by 2025[53]. By the same year, 95% of customer interactions are expected to be driven by AI[54].


## PROJECTS OF INTEREST

The development of AI is taking an interdisciplinary approach, involving fields such as mathematics, computer science, linguistics, psychology, and others.

**Advanced medical diagnosis.** AI aids in analyzing X-rays, MRIs, or CT scans, assisting doctors in disease diagnosis. For example, projects like IDx-DR[55] use AI to detect diabetic retinopathy in retinal images, while Watson for Oncology[56] (IBM) helps oncologists make informed decisions about cancer treatment

52. Gartner Survey Shows 37 Percent of Organizations Have Implemented AI in Some Form
53. Global AI software market size 2018-2025 | Statista
54. What Makes Emerging Technologies The Future Of Customer Experience?
55. IDx-DR - Healthvisors
56. IBM Watson for Oncology

**Prediction of natural disasters.** AI systems analyze vast data, including satellite images and weather data, to predict and manage natural disasters. For example, Google's GraphCast[57] model and "DeepMind for Flood Forecasting" project aim to improve flood prediction accuracy[58].

**Logistics optimization.** AI optimizes transportation routes, inventory management, and demand prediction in supply chains. One example is Amazon's use of algorithms to optimize package delivery and reduce wait times for critical dates[59], while its AWS Stock Depletion Engine model prevents perishable product wastage[60].

**Environmental conservation.** AI is being used in conservation projects to monitor and protect the environment and wildlife. For example, the Wild Me project is using AI models to track and protect more than 50 threatened or endangered species[61].

**Security and surveillance.** AI systems analyze suspicious behavior in public and private environments. For example, Pangiam technology, in collaboration with the Transportation Security Administration (TSA), identifies potential prohibited items in carry-on luggage[62], including the incorporation of TSA PreCheck facial recognition[63] for passenger identity verification.

**Multimedia content creation.** AI generates multimedia content such as music, art, and graphic design. Models like AIVA compose original music for clients like Globant and Vodafone[64].

**Researching new materials.** AI aids in the research and development of materials. For example, ML is being used to simulate and predict the properties of new materials, such as lighter and stronger metals. Projects like the Material Genome Initiative and the discovery of new polar metals and organic light-emitting diodes showcase AI's role in material science advancements[65].

57. GraphCast: AI model for faster and more accurate global weather forecasting - Google DeepMind
58. The Technology Behind our Recent Improvements in Flood Forecasting
59. 5 ways Amazon is using AI to improve your holiday shopping and deliver your package faster
60. AWS Stock Depletion Engine to prevent waste of perishable products | Amazon Supply Chain and Logistics
61. Wild Me
62. TSA Trials Pangiam's AI-Driven Solution To Improve Airport Threat Detection
63. TSA PreCheck®: Touchless Identity Solution | Transportation Security Administration
64. AIVA
65. (de Pablo et al., 2019)

# RECOMMENDATIONS

AI has emerged as a powerful tool to drive innovation in fields ranging from healthcare to business management. However, its implementation entails a number of responsibilities that must be addressed to ensure its safe and responsible use. This requires a comprehensive approach that deals with both technical and ethical aspects throughout the development and application process.

Ensuring the minimization or absence of harmful or unintended consequences during the development of an AI project requires a thorough understanding of the role of accountability principles at each stage: design, implementation and maintenance of AI applications[66].

**Responsible Artificial Intelligence** (RAI) entails designing, developing, and implementing AI systems with the aim of empowering employees and businesses while ensuring equitable impact on customers and society. This practice enables organizations to build trust and expand the use of AI safely and confidently[67].

## FOR DEVELOPMENT

The responsible development of AI demands thorough attention to factors such as effectiveness, robustness, and scalability of the model. Assessing an AI system requires implementing suitable controls to address concerns like information leaks, overfitting, and underfitting[68]. Through iterative continuous improvement, these issues can be mitigated, ensuring the safe and responsible development of AI as a beneficial tool.

68. Uso responsable de la IA para las políticas públicas: manual de ciencia de datos
66. Here's why organizations should commit to responsible AI | World Economic Forum
67. Responsible AI | AI Ethics & Governance | Accenture.

**Scalable infrastructure**. Ensure processing capacity by leveraging flexible and upgradable infrastructures. Companies like Netflix use cloud infrastructures such as Amazon Web Services (AWS) to run AI algorithms for personalized content recommendations across millions of users. This approach adapts to demand fluctuations, ensuring performance even during peak traffic periods[69].

**Governance.** Establish policies and procedures to safeguard the integrity of data used in AI models, simplifying access control and enhancing transparency. Tools like Amazon SageMaker enhance control and visibility over ML models, enabling the capture and sharing of information while remaining vigilant against biases[70].

**Validation and verification.** Before deploying an AI system in a production environment, thorough testing is necessary to validate its operation and verify its accuracy and reliability. For instance, ReLM offers a queryable testing interface for LLMs, facilitating explanation and measurement of behavior directly over large datasets[71].

# FOR SAFE AND RESPONSIBLE USE

Organizations must implement AI in a responsible manner to minimize associated risks. AI auditing involves assessing, mitigating, and ensuring the security, legality, and ethics of an algorithm, identifying both technical and governance risks, and recommending mitigation measures[72].

When evaluating an AI system, it is critical to consider effectiveness, robustness, bias, accountability, and privacy. This includes establishing appropriate controls for managing sensitive data, and creating security protocols to protect system integrity from cyberattacks. Additionally, following best practices that promote transparency and fairness, placing people and their goals at the center of system design, and respecting values such as equity, reliability, and transparency[73].

**Risk assessments.** Regular risk assessments help identify potential threats to the security of AI systems and take preventive measures. For example, Counterfit, an open source tool from Microsoft, makes it easy for organizations to perform security risk assessments on their AI systems to ensure their robustness, reliability and trustworthiness[74].

**Addressing bias:** EIt is essential to ensure fairness and accuracy in automated systems. Training data should be regularly evaluated, discriminatory patterns identified, and appropriate correction techniques

69. Netflix Case Study
70. ML Governance with Amazon SageMaker
71. (Kuchnik et al., 2023)
72. Here's why organizations should commit to responsible AI | World Economic Forum
73. Microsoft Responsible AI Standard, v2
74. AI security risk assessment using Counterfit | Microsoft Security Blog
75. Fairness

applied[75]. For instance, **Google Translate** aims to reduce gender biases in translations through a three-step approach: identifying ambiguous queries, generating gender-specific translations, and verifying their quality before displaying them[76].

**Explainability mechanisms:** Establishing these mechanisms helps to understand how AI systems work and how decisions are made[77]. For example, Microsoft provides details on how user-provided data is processed, used, and stored in its **Azure OpenAI** documentation compendium[78].

# ABOUT ETHICAL CONSIDERATIONS

AI systems raise ethical dilemmas impacting areas such as decision-making, employment, healthcare, education, and more. They can amplify existing biases and challenge notions of human capabilities[79].

In the long term, they could even challenge human uniqueness and autonomy, prompting discussions on self-awareness, social interaction, and human worth[80].

AI systems must empower humans, ensure safety, respect privacy, be transparent, avoid bias, benefit society and the environment, and be auditable to ensure accountability and provide redress when necessary[81].

**Respect for individuals.** Uphold individual autonomy and require protection for those with limited autonomy. Informed consent ensures users are fully aware of risks and benefits, and have the freedom to withdraw consent at any time[82].

**Responsibilities.** Developers and users of AI systems must take responsibility for the decisions and actions taken by these systems. Clear mechanisms for accountability should be established to identify and correct potential errors or misuse[83].

**Impact assessment.** Systematically assess the ethical impact of AI systems in terms of equity, fairness and respect for the rights of individuals and communities using a comprehensive approach. This includes an inclusive workforce, bias assessment, and continuous monitoring[84]. **Fujitsu** provides guidance and a tool to help identify ethical risks, making the risk assessment process easier and more efficient[85].

76. Providing Gender-Specific Translations in Google Translate
77. Explainability
78. Data, privacy, and security for Azure OpenAI Service
79. (UNESCO, 2022)
80. Ídem.
81. Directrices éticas para una IA fiable | Configurar el futuro digital de Europa
82. User data rights
83. Accountability
84. Responsible AI Practices
85. AI Ethics : Fujitsu Global

# ABOUT SECURITY AND PRIVACY

Privacy is often discussed in the context of data protection, privacy and security concerns, which have enabled policymakers to make progress in this area in recent years[86].

**Protection of sensitive data.** Machine learning models often rely on sensitive data (personal, financial, medical, etc.) for predictions, requiring adherence to legal, regulatory, and social standards to safeguard individuals' privacy[87].

**Model security.** This involves ensuring that systems behave as intended (stability) and addressing challenges such as scenario unpredictability and balancing constraints vs. flexibility. Security research in ML focuses on threats such as data poisoning, recovery of sensitive data, model theft, and adversarial examples[88].

**Encryption and anonymization.** Measures like masking, hashing, and encryption are vital for safeguarding user privacy and preventing unauthorized data disclosure. Apple uses techniques such as the **Secure Enclave** and a random ID in Siri to ensure the privacy and security of user interactions with the device[90].

86. AI Ethics | IBM
87. Responsible AI Practices
88. Responsible AI Practices
89. Personal Identifiable Information (PII) Anonymization
90. Privacy - Features - Apple

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