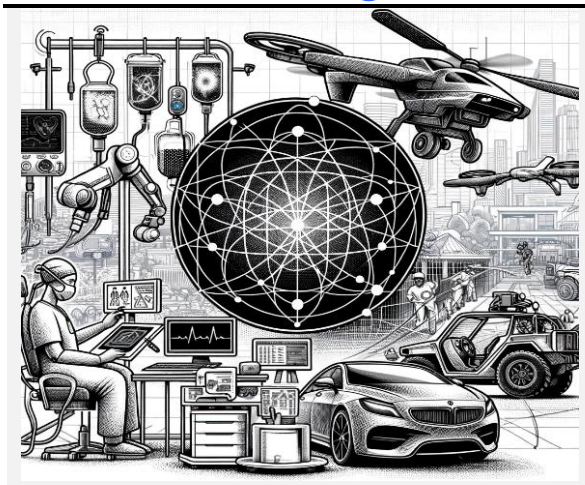
Science & Technology Policy Brief

Artificial Intelligence



The above image was generated by DALL.E, an image generation application, upon the prompt — "generate a composite line art illustration of AI in health, defence, and transport".

Summary

- Currently available AI systems are considered 'intelligent' only within the narrow context for which they are designed.
- AI has use cases in diverse areas such as health, justice, defence, and agriculture.
- Availability of quality datasets and advanced computing is key to the development of AI.
- Certain AI systems use statistical techniques, which may result in errors as well as opaqueness in how they arrive at results.
- Bias in AI may arise from training data as well as design choices, which may perpetuate existing societal prejudices in decision making.

Background

Artificial Intelligence (AI) systems have been in commercial use since at least the 1980s.[1] Recent advancements in AI have been driven by ever-increasing computational power and data availability.[1,2,3,4] Tools like ChatGPT, which can write coherently, code, and answer diverse queries, have raised further curiosity.[5,6] These have fuelled a strong interest in the societal impact of AI.[7,8,9,10,11] Efforts to regulate AI are underway in jurisdictions such as USA, European Union, and China.[12,13,14]

Owing to its transformative potential across diverse sectors, AI is considered to be of strategic importance. In India, the National Strategy for Artificial Intelligence was formulated in 2018.[15] The Strategy highlighted healthcare, agriculture, education, smart cities and infrastructure, and transport as key focus areas for the adoption of AI.[15] In October 2023, the Expert Group on AI constituted by the central government presented its first report.[16] The report provides a blueprint for operationalising the AI ecosystem in India.[16] The proposed Digital India Act is expected to regulate AI systems to some extent.[17,18]

This note explains the technology behind AI systems, its use, and related concerns. We mainly discuss concerns with AI systems that may be considered 'intelligent' only in narrow contexts. The potential effects of Human-like AI (Artificial General Intelligence) or Superintelligence (machine surpassing human intelligence) on society are not covered in this note.[19,20] Presently, these are considered technological frontiers, with varied opinions on their realisation and timeline (see Box 1 on page 2).[7,19,21,22]

Introduction

There is no universally accepted definition of AI.[2] The primary difficulty arises from defining 'Intelligence'.[23,24] A question often debated is that if a machine can do a task that requires human intelligence, does that make it truly intelligent, or is it just mimicking intelligence.[2,24,25,26] Broadly, AI refers to the ability of machines to perceive, understand language, learn, reason, and solve problems. These are akin to intelligence characterised with human cognitive processes.

AI systems can be software or a combination of software and hardware (e.g., robots or autonomous vehicles).[27] AI systems differ from traditional software programs in their approach to problem-solving. Traditional software executes explicit instructions provided by a programmer in a pre-determined order. In contrast, AI systems exhibit the ability to adapt; they can plan and search for optimal solutions or learn from data and improve their performance over time.[2] For instance, AlphaGo Zero is an AI system that could learn the board game of 'Go' purely by playing against itself.[28] It defeated its predecessor, AlphaGo Master (by 89 games to 11), which had beaten the world's number one human player (by three games to zero).[28,29] Go, played on a 19x19 grid, is considered more complex than chess.

Currently available AI systems are considered intelligent only in a narrow sense, i.e., a system which shows intelligent behaviour in one domain, may not be relevant in another. For instance, AlphaGo Zero may not be able to translate a paragraph from Chinese to English, something Ke Jie, the world no. 1 Go player beaten by AlphaGo Master, can be expected to do easily. Thus, these

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systems are referred to as 'Narrow AI'. This sets them apart from humans, who exhibit intelligent behaviour in very diverse areas. Hence, two key frontiers in AI development are considered to be: (i) 'Artificial General Intelligence' (AGI) – intelligence across a wide range of tasks and domains, similar to humans, (ii) 'Superintelligence' – where machine intelligence surpasses human intelligence across all domains and tasks.[19,20]

Box 1: Existential Risks from AI

There has been intense debate on whether AI presents existential risks for humanity.[30,31,32,33,34,35] These are concerns with scenarios where a superintelligent AI may act independently, pursue goals misaligned with human values, and thereby cause harm on a large scale.[19] These stem from the risks of development of self-preservation instinct, capability to self-improve, and loss of human control.[19] In a 2022 survey of AI researchers, the forecast time to a 50% chance of human-level AI was around 37 years, i.e., 2059.[20] A median respondent believed that there is a 5% probability of an extremely negative long-term impact of AI.[20] They acknowledged the need for increased focus on AI safety research.[20] However, past predictions regarding advancements in AI have proven to be overly optimistic.[1] Some leading researchers have argued that current approaches are unlikely to lead to human-level AI.[36,37]

Approaches for building AI Systems

Based on the approach to represent and process information, techniques to build AI systems are broadly classified into two key categories. Many systems may utilise both of these approaches.

Rule-based Systems: These systems use human-encoded knowledge, rules, and logical inferences.[2,19] They mimic the reasoning of a human expert in solving a problem. They can plan and search through encoded knowledge and rules to solve a given problem. 'Deep Blue', which defeated the world chess champion Garry Kasparov in 1997, is an example of such a system.[38] It searched through millions of possible moves encoded in advance, and attempted to find the best move by exploring as many possible moves ahead in the game.[39]

Such an approach works well where there may be relatively clear-cut goals and rules to achieve them.[2] Another advantage may be that the reasoning process may be relatively transparent and interpretable. However, such approaches have typically fallen short in applications likely to encounter very high variations and uncertainty in input. For instance, rule-based approaches could not achieve great results in translating between languages or recognising images.[40] The number of combinations or variety in input may be too large to handcraft clear-cut rules around them.

Machine Learning: These systems use statistical techniques to induce trends from patterns in data.[2,19] They learn and improve from the data they work with, and are able to generalise from the patterns they see in the examples.[41] Generalisation refers to the ability to generate acceptable output for previously unseen input. Translation may be a good example to understand the differences between rule-based approach and machine learning. In a rule-based translation system, a human programmer would encode rules of grammar of two languages, a dictionary of words, and some rules on semantics. On the other hand, a machine learning-based system would start by screening a large sample of already translated texts and inferring patterns from these examples.

The performance and quality of machine learning systems are also reliant on training data.[42,43] The performance may degrade if the input data differs significantly from the training data. Monitoring, re-training, and updates may be required in fast-evolving contexts. Some of the more complex systems are often seen as 'black boxes'; it may be challenging to explain their reasoning.[4]

Recently launched applications such as ChatGPT, Bard, and DALL.E are classified as Generative AI. Generative AI is a sub-field of machine learning, which refers to the capability of generating novel content including text, images, music, and videos.[44] These systems also learn patterns and relationships in vast amounts of already available data.[45] They utilise these learnings to generate new but similar information by predicting the statistically most likely response.[46,47] Their ability to generate content is bounded by their training data.[37,48]

Table 1: Some AI Technologies

Technology	Description	Examples
Computer Vision	Interpreting visual data, recognising objects	Health diagnostics, facial recognition
Natural Language Processing	Understanding and analysing human language	Search engine, machine translation, spam detection
Speech Recognition	Processing spoken language	Speech-to-Text input
Generative AI	Generating new text, images, audio, and other data on prompt	ChatGPT, Bard, DALL.E, Midjourney
Recommendation Systems	Providing personalised suggestions	Content and shopping recommendations
Predictive Analytics	Predicting future outcomes based on historical data	Weather forecast, fraud prevention and detection
Robotics	Machines that move and act autonomously	Industrial robots, drones

Sources: Russell, S., & Norvig, P. (2020); Calvino, F., et al. (2023); PRS.

Use cases of AI

AI has applications across diverse sectors, aiding advanced capabilities and efficiency (Table 2 on the next page). The National Strategy on AI highlighted the following as key challenges for the development of AI in India: (i) availability of quality datasets and advanced computing, (ii) lack of research in foundational technologies, (iii) talent gap, and (iv) unclear regulations on privacy, security, and intellectual property rights.[15]

Table 2: Illustrative list of use cases of AI

Area	Applications
Healthcare[49,50,51]	Diagnosis including interpretation of medical imaging such as cancer detection, prediction of health risks, recommendations on treatment plans, virtual health assistants, drug discovery, robotic surgery
Education[52,53]	Personalised learning, learning content creation, automated grading and feedback
Finance[54,55,56,57]	Fraud prevention and detection, credit scoring, risk modelling for insurance, algorithmic trading and investment
Transport[58,59,60]	Driver assistance, traffic management, navigation, route optimisation, logistics planning, autonomous vehicles
Policing[61,62]	Predicting criminal hotspots and patrolling routes, facial recognition to identify suspects, automated traffic challan, profiling of suspects, crime pattern analysis, social media monitoring to identify threats
Judiciary[63,64,65]	Legal research, summarisation and translation of case laws, case allocation, recommendation on bail, parole and sentencing, prediction of case outcomes and risk of re-offending
Defence[66]	Border patrolling, autonomous combat vehicles, autonomous weapon systems
Media[67,68]	Content recommendation and personalisation, content writing, sentiment analysis, content moderation
Manufacturing[69,70]	Product design, process and task automation, industrial robots, predictive maintenance, demand forecasting
Retail[71,72]	Customer profiling, targeted advertising, purchase recommendations, automated grievance redressal system
Agriculture[73]	Autonomous equipment for field work, crop planning, automated detection of pathogens, yield prediction
Research[74,75,76]	Generation of new research hypotheses, exploratory data analysis, modelling, simulation

Sources: Refer to endnotes marked in the 'Area' column; PRS.

Concerns with Use of AI

While AI has the potential to transform a wide range of sectors significantly, its usage has also raised certain concerns discussed below.

Errors

Where AI systems apply probabilistic approaches, there remains a possibility for error. Errors may be accentuated by problems with training data and gaps in design.[77,78] Consequences of such errors may be severe in many applications such as healthcare and legal systems. For instance, when facial recognition over a video feed gives an incorrect match, it could result in a wrongful arrest.[79,80,81] A series of assessments of facial recognition systems by the National Institute of Standards and Technology of USA has shown a significant reduction in error rates over the years.[82,83,84,85] However, error rates continue to be relatively higher for certain demographic groups such as women, children, elderly, and races such as African and Asian persons.[86,87] Further, accuracy may vary widely across developers.[85,86]

Generative AI systems sometimes show behaviour characterised as 'hallucination'.[88,89] They present information that may be inaccurate, irrelevant, or non-existent, as if they are correct.[88,90,91] Such inaccuracies may be a limitation in their usage in areas such as searching, summarisation, and programming. For instance, errors in information retrieval may result in misinformation.

Bias

Another critical challenge that often intersects with errors is bias. Bias refers to systematic discrimination against certain groups and categories. For instance, a 2016 analysis of COMPAS, an AI system deployed to predict the risk of re-offending in USA, showed that white persons were less likely to be termed high-risk; whereas black persons were more likely to be termed high-risk.[92] Similar racial bias has been found in the predictive systems to guide health decisions.[93] The system in question identified which patients will benefit from high-risk care management programs. Most social media platforms deploy some or other form of automated content moderation to keep harmful content away. Ethnic and gender-based bias has been observed in systems to detect offensive speech online.[94]

Bias may creep in at various levels including training data, algorithm design, and feedback cycles.[95,96,97] As many predictive or recommendation systems are trained on historical data, societal prejudices or biases in the real world also become part of the model through the training data.[98] Similarly, under-representation of certain groups in datasets may adversely impact the quality of results for those groups.[97] By not recognising such biases in data, developers may also perpetuate such biases. Developers may introduce or reinforce biases when they select or assign priorities.[99] Bias may also be observed if the system is used in contexts or with audiences who may not have been accounted for at the design stage.[100]

Explainability

AI systems, especially machine learning systems, use approaches where it may be challenging to determine how a decision was arrived at.[101,102] This limitation may pose a challenge in their adoption in high-risk areas such as justice, healthcare, and finance. Explainability may be necessary for user trust and confidence in the system.[103] Lack of explainability may also be incompatible with existing regulations and standards. For instance, in case of justice, explainability may be considered necessary for adherence to established norms of due process and reasoned orders. Further, it could also act as a safeguard against errors and biases.

Transparency

Another issue is related to a lack of information in the public domain about how these systems exactly work.[104] For instance, the underlying algorithms or datasets may not be publicly accessible.[104] This reduces opportunities for communities to evaluate capabilities as well as risks, which could help in identifying the pitfalls of such systems. Lack of transparency may lead to a lack of evidence to guide their adoption and also erode the trust in the overall system. Arguments also exist against making systems totally transparent, as this may lead to easy replication for misuse, cyber attacks, or revealing of trade secrets.[104,105]

Accountability

Determining responsibility for issues or errors with AI systems is a complex and evolving area of discussion.[23,106] The opaque nature as well as complexity of AI systems may make it difficult to pinpoint individual responsibilities in systems that involve multiple actors and resources.[96] For instance, a question may arise who is responsible for the accident of an autonomous car, resulting in the death of a person crossing the road.

Currently, in areas such as justice, AI systems have not replaced human decision-making; they only aid them.[65] Human oversight is built in as a safety mechanism.[107,108] However, users of such systems may exhibit cognitive bias where they place excessive trust in automated systems (referred to as automation bias), even where it contradicts their own judgement or expertise.[108] This may limit the effectiveness of the human oversight process.

Privacy

Many AI systems are trained on the personal information of individuals. Current privacy protection laws are based on the principle of data minimisation to protect privacy.[109] This means that the least possible data should be collected to meet a purpose, and data should be deleted once the purpose is fulfilled. These principles may be in tension with the nature of AI systems. Machine-learning-based systems need large amounts of data for training and testing algorithms.[36] For instance, the accuracy of facial recognition technology has been improved with large datasets built from publicly available photos over internet.[110] Such systems have faced lawsuits under privacy laws. In Australia, the Privacy Regulator ordered Clearview AI to delete its datasets.[110] AI systems may combine datasets to infer new insights about a person, which may also pose privacy risks.[40]

Intellectual property rights

Questions have emerged on two key grounds: (i) whether original works may be used in training without a license, and (ii) who owns the intellectual property rights for the AI-generated content or invention between the developer and the human operator.[23,111] Generative AI systems may generate content which may not be sufficiently distinct from the copyrighted training data, and can then be prone to copyright challenges.[119,120] Image generation applications such as Stable Diffusion and Midjourney are facing lawsuits for using datasets compiled from scraping the web indiscriminately, which may include copyrighted creations.[121,122] The question arises whether training of AI systems may be covered under fair use.[119,123] Existing copyright laws allow fair use, i.e., use for criticism, comment, reporting, teaching, scholarship, or research.[119,124] Currently, under intellectual property laws worldwide and also in India, rights are given only to human creators.[23,111,119,125] Any AI-generated content or invention is not eligible for copyright or patent, respectively. On the other hand, it may be argued that lack of such rights may be a disincentive for persons who build, own, and use AI.[23]

Box 2: Regulation of AI around the world

European Union: A draft law proposing risk-based regulation is under consideration.[112] Certain applications are sought to be restricted, which include real-time biometric identification systems in public places. Prior impact assessment and regular audits would be mandatory for areas such as health, law, public services, and employment, which intersect with fundamental rights.

USA: In October 2023, the President issued an Executive Order regarding the regulation of AI.[113] The Order provides for the development of standards for testing before the public release of certain AI systems. It requires the government to take steps to protect privacy, address discrimination, and ensure safety. An AI Bill of Rights has been proposed.[114] A local law in New York City regulates the use of AI in employment.[115,116]

China: In China, regulations are in place for certain specific aspects of AI. For instance, separate regulations provide for the use of recommendation algorithms, certain machine learning applications, and Generative AI applications.[117]

India: In 2021, NITI Aayog released a Responsible AI framework which outlines key principles for managing AI.[118]

Employment

While previous technological advances in automation have affected routine or repetitive tasks, AI has the potential to automate non-routine tasks including creative and analytical tasks.[11,126,127] For instance, AI systems can write computer programs and fix bugs in software.[128] Advancements in AI may expose large parts of the workforce to potential disruption. This may happen for both low and high-paid jobs.[127]

Like earlier technological advances, the adoption of AI may also lead to the creation of new types of occupations. For instance, 60% of the employment in 2018 in the USA was in jobs that did not exist in the 1940s.[127] In the case of currently available Generative AI, an ILO study (2023) observed that their adoption is more likely to automate certain parts of jobs than substitute the human worker entirely.[127] However, the impact may be high for certain roles. For instance, clerical work may be more exposed to risks of replacement by AI.[127]

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