Telematics and Informatics Reports 20 (2025) 100265

Contents lists available at ScienceDirect

Telematics and Informatics Reports

journal homepage: www.elsevier.com/locate/teler

Artificial Intelligence (AI): Foundations, trends and future directions☆

Muhammed Golec [a], Emir Sahin Hatay [b], Sukhpal Singh Gill [a,*], Rajkumar Buyya [c]

[a] School of Electronic Engineering and Computer Science, Queen Mary University of London, United Kingdom
[b] School of Computer Science and Electronic Engineering, University of Essex, United Kingdom
[c] Quantum Cloud Computing and Distributed Systems (qCLOUDS) Laboratory, School of Computing and Information Systems, The University of Melbourne, Australia

ARTICLE INFO

Keywords:
AI
Computing
Quantum computing
Artificial intelligence
Machine learning

ABSTRACT

Developments in artificial intelligence (AI) technology have revolutionized many areas, from health to education, and from defense to commercial applications, both civilian and military. This article provides a comprehensive overview of the foundations, theoretical, and technological developments of AI, and the application areas it has enabled. It also examines the industrial impact of AI, including recent trending applications such as DeepSeek, ChatGPT, Google Lens, Face ID, and Tesla, as well as the areas of Natural Language Processing, Autonomous Vehicles, and Computer Vision. Beyond these, it highlights on future aspects of AI, such as next-generation Large Language Models (LLMs) and Artificial General Intelligence (AGI), and explores its impact on social ethics. The investigation of all these aspects aims to equip the reader with a comprehensive understanding of the current impact and potential future directions of AI.

1. Artificial intelligence: Unveiling the future

Artificial intelligence (AI) is perhaps the most effective technology of the 21st century, based on the principle of Machine Learning (ML) by imitating human intelligence [1]. Advances in processor and chip technologies have accelerated the adoption of AI in various fields such as industry and the defense sector [2]. Furthermore, AI has evolved rapidly from rule-based learning to Deep Learning (DL), which shows high performance in complex tasks. Contrary to popular belief, the foundations of AI are not based on Computer Science, but on multiple disciplines such as mathematics (statistics) and cognitive science [3]. Before the development of computer technologies, AI studies were mostly based on theoretical foundations, but thanks to processor technologies that can reach high capacity and speed, especially in the 21st century, they have started to produce solutions to real-world problems with practical studies [4].

Today's AI applications aim to reduce the mortality rate of diseases and unnecessary health expenses with early diagnosis applications in the field of health [5]. In finance applications, it provides convenient information for banks, such as credit risk analysis by learning from customer data from the past [6]. Despite all this potential that AI makes human life easier, it still brings with it challenges such as user privacy and fairness in hiring (algorithmic bias) [7]. In addition, to address these concerns, researchers from academia and the private sector continue to work.

Fig. 1 shows the organization of the article, which provides the reader with an overview by presenting the basic principles, historical developments, and current applications of AI. In addition, it aims to provide research gaps for researchers by emphasizing the future directions of AI.

1.1. AI through the ages: A brief history

AI has evolved with contributions from different disciplines and scientists from the past century to the present, and key milestones of this process are noted in Fig. 2 [1]. In the 1950s, Turing introduced a test that was accepted as a criterion for evaluating whether machines were intelligent enough to deceive humans [8]. In the following years, the term *"AI"* was first introduced at a conference held in Dartmouth under the leadership of scientists such as McCarthy, Minsky, Shannon, and Rochester [9]. By the 1980s, the use of AI began to be seen in industry and healthcare [10]. The development of DL algorithms became a rapidly developing field with the contributions of scientists such as Hinton, LeCun and Bengio in the field of neural networks [11]. With the introduction of high-powered processors, AI has evolved, leading to major advances in areas such as Natural Language Processing (NLP), Large Language Models (LLMs), and Computer Vision (CV). Popular applications today include ChatGPT, Deepseek, and Google

☆ This article is part of a Special issue entitled: 'CompComm & MediaPrax' published in Telematics and Informatics Reports.

* Correspondence to: School of Electronic Engineering and Computer Science, Queen Mary University of London, London, E1 4NS, UK.
E-mail addresses: m.golec@qmul.ac.uk (M. Golec), eh22360@essex.ac.uk (E.S. Hatay), s.s.gill@qmul.ac.uk (S.S. Gill), rbuyya@unimelb.edu.au (R. Buyya).

https://doi.org/10.1016/j.teler.2025.100265
Received 13 February 2025; Received in revised form 5 September 2025; Accepted 17 October 2025
Available online 20 October 2025

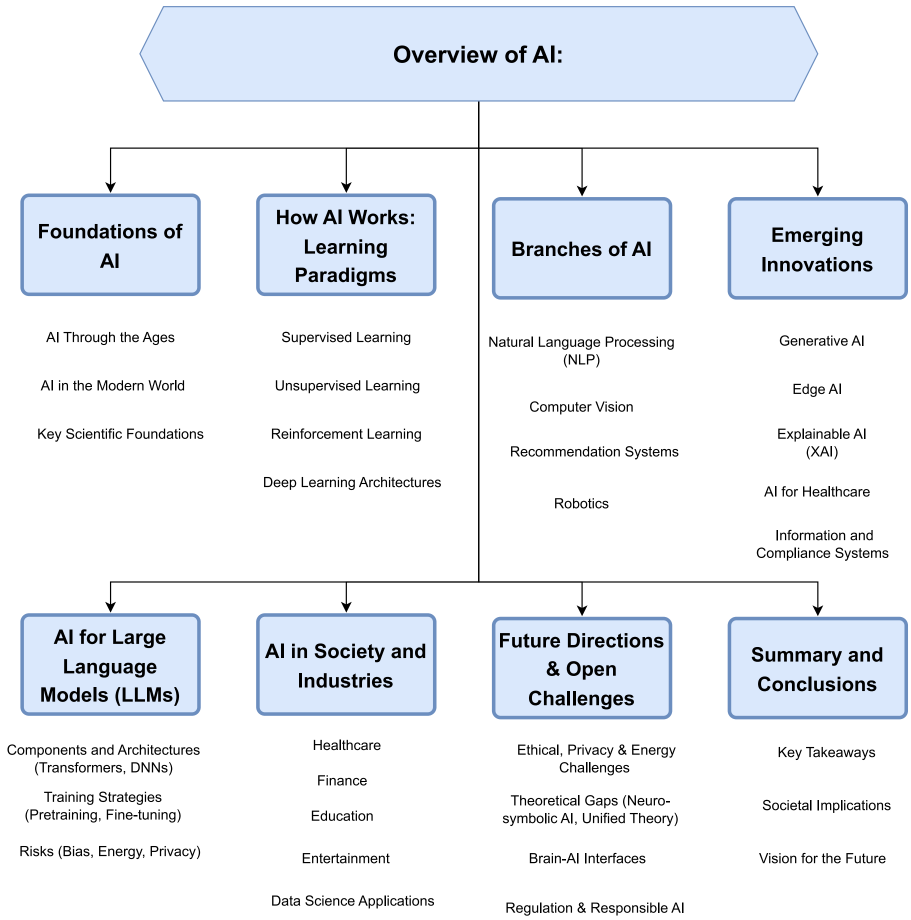

Fig. 1. Overview of AI: Foundations, Trends, and Future Directions.

AlphaGo, which are good examples of these developments [12]. From the 2020s onward, AI has begun to evolve into a more creative form, successfully simulating human cognitive processes, as in Generative Pre-trained Transformer 4 (GPT-4).

1.2. AI everywhere: How it's shaping the world

Fig. 3 is a depiction of the breadth of AI use and AI is seen in almost every field. The popularity of AI is largely driven by the developed ML and DL techniques [13]. For example, while AI-based early diagnosis systems have attracted great attention in the healthcare field, personalized education platforms for students have also recently become popular [14]. Beyond all this, it will continue to shape our lives in the near future with developments such as recommendation engines and autonomous vehicles.

2. Building blocks of AI: The science behind intelligence

AI, which is born from the combination of many different disciplines, basically works on the principle of modeling and then learning by processing data [15]. This can basically be summarized as the analysis of large-scale data (dataset) and teaching algorithms under high processor power (data engineering).

2.1. The pillars of AI: Key scientific foundations

AI models rely on multiple scientific foundations, such as mathematics, statistics, and neuroscience, to learn from data and make decisions. Some of these disciplines can be grouped under the following three general headings [16]:

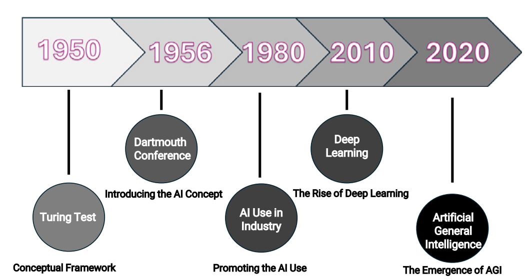

Fig. 2. Key milestones in the history of AI.

1. **AI Fundamentals I - Statistics:** AI models work on the foundations of probability and statistics to draw meaningful conclusions [17] and use statistical methods such as median, regression analysis, and clustering when establishing correlation relationships and grouping data [18]. Examples of this include the use of methods such as Bayes' Theorem and Markov Models in probabilistic computations (email spam detection) and time series forecasting (weather forecasting) [19]. Furthermore, statistical learning is very useful for model generalization in high-dimensional spaces. Bias–variance tradeoff and statistical significance are frequently used metrics in model robustness analyses. Bayesian DL is used in conjunction with neural networks for uncertainty-aware system activation for safety-critical applications.
2. **AI Fundamentals II - Neuroscience**: AI learns and interprets data by imitating neurons in the human brain [20]. For this

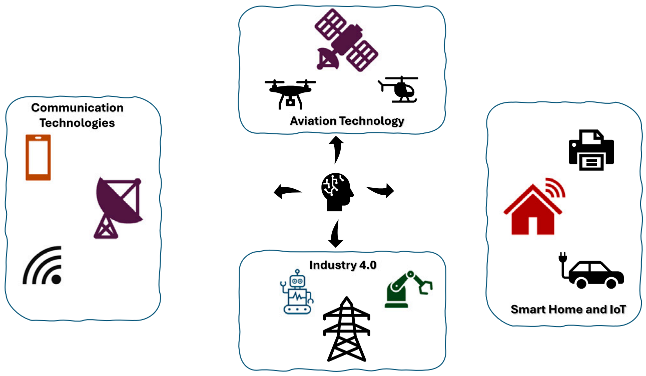

Fig. 3. AI everywhere: Transforming industries and everyday life.

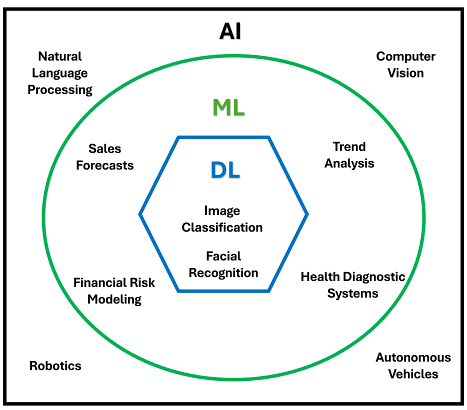

Fig. 4. The hierarchical relationship of AI, ML, and DL.

reason, the contributions of neuroscience are very valuable in learning and interpreting data. Neuroscience draws inspiration from the structure of biological neurons, synaptic plasticity, and hierarchical information processing in the cortex. For example, Convolutional Neural Network (CNN) is inspired by the neuronal receptors of the visual cortex.

3. **AI Fundamentals III - Deep Learning**: DL is a sub-branch of AI and consists of multi-layered neural networks to work effectively on complex data [21]. Today, it is frequently used in image processing and time-series estimation applications [22]. The concepts of AI, ML, and DL are often used interchangeably and can be confused. Fig. 4 is given to better explain the hierarchical relationships between the concepts of AI, ML and DL. Artificial intelligence refers to a broad field of computer systems that mimic human intelligence in tasks such as learning and problem solving [23]. NLP-related applications such as DeepSeek and ChatGPT, which have become popular recently, are examples of this field [24]. ML is a subfield of AI and includes algorithmic techniques that improve model performance using training data [25]. Sales forecasting and health diagnostic systems are examples of applications of this field [26]. DL is a subfield of ML and performs well in complex tasks using artificial neural networks [25]. Image classification and face recognition are examples of applications of this field [27]. DL models are practical for end-to-end learning pipelines because they can automatically extract features. CNNs and Transformer architectures perform well on language tasks through techniques such as attention mechanisms. However, DL models suffer from limitations such as overfitting, and therefore, research on DL continues.

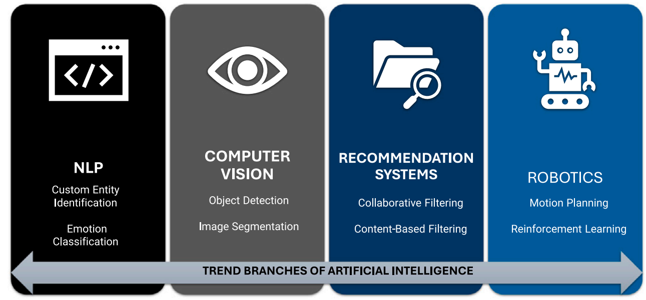

Fig. 5. Trend branches of AI.

2.2. How AI works: Essential methods and strategies

AI is examined under three main headings according to the type of learning [28]:

1. **Supervised Learning**: This is a model where labeled data is used when training AI models, and spam filtering can be given as an example [29]. In Supervised Learning (SL), a known dataset of known labeled input–output pairs is trained, and the most well-known examples include Decision Trees, Support Vector Machines (SVM,) and Gradient Boosting [30]. Out of these examples, the decision tree algorithm iteratively splits the data to reduce the noise measured by the Gini Index or Entropy [31]. One of the challenges faced in SL is that the models perform well on training data but generalize poorly on unseen data (overfitting) [32]. The most common methods used to solve this problem are techniques like cross-validation [33]. SL learns from labeled data and is used in many areas, such as medical diagnosis and fraud detection. SL models, such as Random Forests, reduce variance by combining multiple learners, thus increasing robustness.
2. **Unsupervised Learning**: This is a model where AI models learn from unlabeled data, and segment customers according to their habits can be given as an example [34]. The most popular of these models, which uncover hidden patterns in situations where data labeling is difficult, are K-Means and Density-Based Spatial Clustering of Applications with Noise (DBSCAN). They are frequently used in scenarios such as dimensionality reduction and anomaly detection. The most common challenge is assessing model performance due to incomplete labeled outputs.
3. **Reinforcement Learning (RL)**: These are models where the AI model (agent) works in the form of trial and learning by getting reward and penalty, and autonomous vehicle scenarios can be given as an example [28]. The most well-known examples of RL include Q-Learning and policy gradients, where agents learn action Q(s,a) for state [35]. One of the known challenges in RL is the exploration-exploitation trade-off that requires agents to balance between state a and s, and new techniques such as epsilon-greedy exploration and deep Q-networks (DQN) have been developed to address this problem [36]. RL uses Markov Decision Processes (MDPs) to model decision-making. Proximal Policy Optimization (PPO) and Actor-Critic methods are frequently used in complex environments such as robotics and strategic games.
4. **Deep Learning**: DL models, such as Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs), are frequently used methods, especially in application areas such as image recognition [37]. CNNs apply convolutional filters to detect hierarchies in image processing, which allows the model to achieve high prediction accuracy [38]. Despite all their advantages and high performance, DL models have some disadvantages, such as requiring large labeled datasets and high computational resources. Moreover, overfitting is still one of the

major challenges, and methods such as batch normalization and attention mechanisms have been proposed to overcome all these problems [39]. The development of transformer architectures has led to significant advances, particularly in the field of LLM. Pre-trained models such as BERT and ResNet are frequently used for fast convergence and successful generalization with limited labels.

2.3. AI's diverse landscape: Exploring its many branches

It is possible to divide AI into many sub-branches according to the focused problem and the domain of work. All these sub-branches shown in Fig. 5 contribute to AI's ability to learn and solve problems in very wide areas. In this subsection, we will try to examine the most popular AI sub-branches of recent years:

1. **Natural Language Processing (NLP)**: It is a branch of AI based on AI's processing of human languages, and its most popular applications today include ChatGPT, Google Translate, Siri [40].
2. **Computer Vision**: It is a branch of AI based on AI's processing of visual content (such as images, videos), and its most popular applications today include Apple Face ID, Google Lens, Google DeepMind [41].
3. **Recommendation Systems**: It is a branch of AI based on AI's processing of user behavior (purchase history, etc.), and its most popular applications today include eBay, Amazon Kindle, YouTube recommendation systems [42].
4. **Robotics**: A research field based on the integration of AI into mechanical systems, especially with Reinforcement Learning frequently used. This field, led by companies such as Boston Dynamics and ABB Robotics, is developing rapidly, especially with the intelligent automation systems offered by Industry 4.0 and Industry 5.0 [43].
5. **AI in 6G Ecosystems**: AI technologies have accelerated decision-making in various technology areas, such as autonomous vehicles and real-time applications, enabling low latency [44]. Therefore, they are expected to play a central role in future communication networks, particularly in 6G. Literature confirms that efficient, privacy-sensitive, and scalable technologies like EdgeAI and Explainable AI (XAI) can be integrated into the 6G ecosystem [25].

3. AI innovations: The cutting-edge technologies shaping the future

This subsection describes recent technological developments in the field of AI listed in Fig. 6.

1. **Detection Systems:** These systems use AI to detect environmental effects [42]. The most well-known applications include computer vision, where images are interpreted, and speech processing, where audio data is analyzed [45]. Outside of this area of use, it is frequently used in various applications such as autonomous vehicles and smart home systems.
2. **Generative AI:** These systems use AI to generate new content [46]. The most well-known examples include Deepfake, where fake images can be generated [47]. It revolutionizes many fields, including education and art, as well as simulated historical figures and new forms of creativity. With the high speed and large data transfer capacity that 6G will bring with it in the early 2030s, GENAI is expected to play an important role for holographic communication and immersive applications [46, 48].
3. **Edge AI:** These systems are created by integrating Edge and AI models [49]. Thanks to the edge devices used in EdgeAI, processing power is brought closer to the data source [50]. In this way, low latency and low bandwidth usage are aimed [51]. Low latency and low bandwidth usage mean that EdgeAI will provide great advantages in industrial applications.
4. **Natural Language Processing:** These systems use AI to process and interpret human language [52]. The most well-known examples are ChatGPT and applications where sentiment analysis is performed [53]. With the development of transformer-based models and increasing competition in the sector, NLP-based applications are expected to gain great momentum.
5. **Explainable AI (XAI):** These are systems that aim to make the use of AI in decision-making processes transparent and at a level that everyone can understand [54]. It is frequently used in credit scoring applications.
6. **AI for Healthcare:** These systems aim to integrate AI into healthcare applications to ensure early diagnosis and prevent unnecessary drug use [55]. They are also frequently used in developing areas such as robotic surgery.
7. **Information and Compliance System:** These systems use AI in information processing and optimization processes [56]. In these systems, large amounts of data are processed quickly, and the aim is to extract meaningful information for company policies.

4. AI innovations empowering LLMs

Recent developments in AI have gained momentum with the emergence of LLMs such as GPT-4, BLOOM, and ChatGLM [57]. While training these models, a large number of data and parameters are used, and with this processing capacity, LLMs have shifted AI from perceptual to cognitive intelligence. Contrary to all these capabilities, LLMs face risks such as high energy consumption, bias, and privacy [58]. To overcome these limitations, there are strategies such as increasing computational capabilities and integrating neural-symbolic reasoning frameworks [57]. In the near future, LLMs are expected to shape the next generation of AI technologies.

Fig. 7 shows the basic components for LLMs using large-scale data, transformer-based architectures, and deep neural networks. LLMs learn through self-supervised pre-training and adapt based on criteria such as domain-specific fine-tuning and application domains [58]. This significantly increases the flexibility and scalability of LLMs.

5. AI for computational social sciences

AI has made great contributions to the transformation of Computational Social Sciences and has made traditional social science theories more objective and scalable with new techniques such as big data, network theory, and NLP [59,60]. For example, DL models can be used to prevent the spread of misinformation in large mass events. Fig. 8 shows the intersection of Computational Social Sciences (CSS), computer science (CS), and social science (SS). Social events can be analyzed in a more systematic and data-oriented manner with new research areas that emerge with the combination of sub-branches of CS, such as ML, DL, and sub-branches of SS, such as psychology and political science.

6. AI in action: Transforming industries and daily life

AI has gained momentum over the last decade and continues to transform many industrial areas.

1. **AI in Healthcare**: With its entry into healthcare applications, AI has brought many promising developments, such as successful early diagnosis of diseases and personalized treatment plans [5]. In particular, it is expected to become widespread in most healthcare services in the future, as it offers higher success than human doctors in some cases such as image analysis in radiology and in cancer detection [61]. In addition, it is expected to

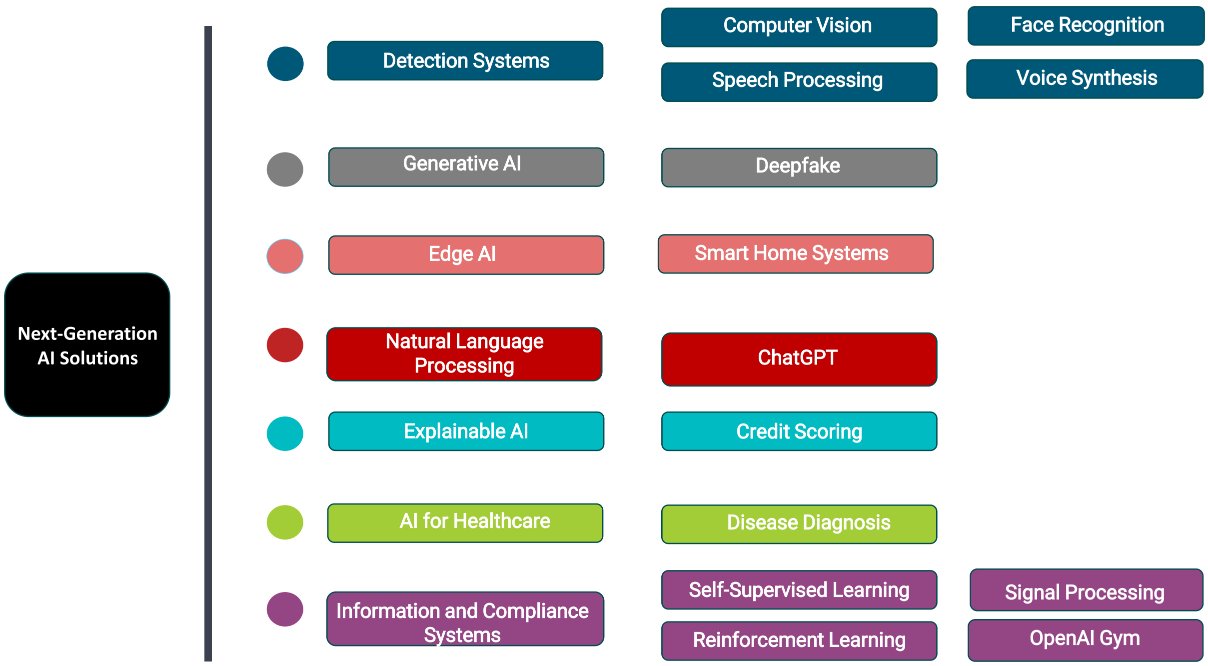

Fig. 6. Next-generation AI solutions highlighting technological advancements.

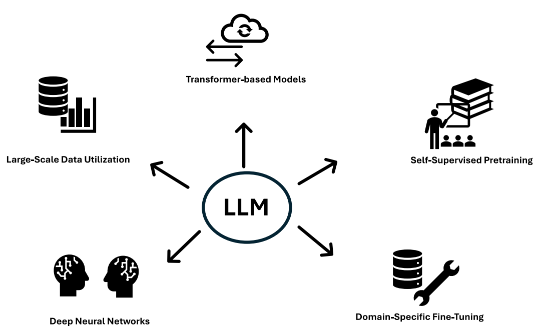

Fig. 7. Key components driving the development of LLMs.

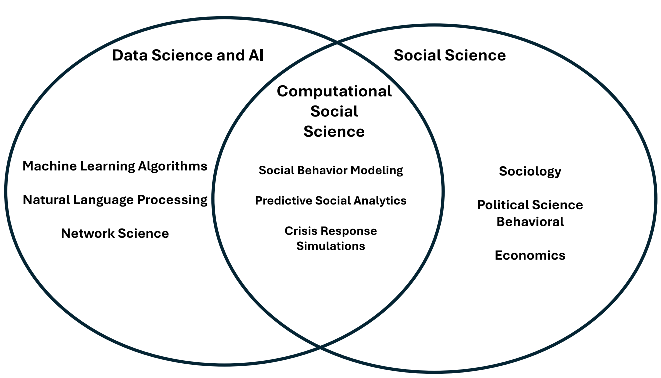

Fig. 8. Computational social sciences: Disciplinary intersection.

make great contributions to genetics and pharmaceutical science in the future with the integration of high-processing capacity quantum computing and AI [43].

2. **AI in Finance**: Increasing fraud cases in recent years increase the need for AI-supported risk management applications. Using AI, anomaly detection and abnormal spending detection applications are used by some banks [6]. On the other hand, AI supports conscious credit decisions by providing credit scores to banks by looking at customers' past data [6].
3. **AI in Education**: With the introduction of AI-based systems into education, students' strengths and weaknesses are analyzed and special learning programs are offered to students [62]. In this way, it is aimed for students to benefit from education at the optimum level. In addition, AI-based systems, it has the potential to reduce the burden of teachers' exam and homework evaluation [63].
4. **AI in Entertainment**: With the entry of AI into various entertainment areas such as games, movies, and music, higher quality content has begun to emerge [64]. In particular, in parallel with the rapid developments in the gaming industry, more dynamic content is provided for players, while the resources of game consoles and computers are operated in a more optimized way [65]. In this way, it is aimed to provide both a better gaming experience for players and to reduce system-related restrictions (insufficient RAM, etc.).
5. **AI for Data Science**: AI and data science complement one another since big data supplies the massive volumes of data needed by AI for model training and learning [66]. The two are mutually supportive; AI improves big data's analysis and knowledge, and big data helps AI systems adapt and expand. To discover trends and provide precise forecasts, AI algorithms, particularly machine learning algorithms, need to be trained on big datasets [67]. Further, Quantum AI can sift through piles of big data in search of knowledge and trends that might otherwise go overlooked [68]. This capability paves the way for improved forecasting, analyzing data more rapidly, and more trained decision-making across disciplines [69].
6. **Advanced Applications of AI**: AI usage areas are rapidly spreading in various areas such as healthcare (ChatGPT in healthcare education) and automotive (Tesla autonomous vehicles). In this subsection, some examples of AI usage areas are discussed in order to provide more concrete information to the reader.

   (a) **ChatGPT in Healthcare Education**: ChatGPT is a service that generates human-like text responses using LLMs after being developed by OpenAI [70]. It can be used in the healthcare field to inform patients by translating complex medical information into simpler language [71]. Moreover, it can provide preliminary mental health triage for patients receiving consultation treatment [72]. ChatGPT, which has recently started to be used in medical training simulations, can perceive patient understanding more successfully than traditional text-based sources [73]. However, one of the challenges of ChatGPT in this field is that RL-based human feedback (RLHF) is still needed to increase accuracy.

(b) **Tesla's Autopilot and Full Self-Driving (FSD) Systems**: Tesla has gained autonomous driving capability with DL models that process visual, ultrasonic, and radar data [44]. Tesla, which also uses fleet learning method and uses data collected from millions of vehicles to develop this capability, has reportedly had few accidents while an autonomous pilot is active, according to reports published in recent years [74]. However, there are still ongoing discussions about AI-related ethical and legal responsibility for uncertain driving scenarios.

(c) **Google Lens in Visual Search and Accessibility**: Google Lens performs object recognition and text extraction (OCR) operations using methods such as convolutional neural networks (CNNs) and transformer architecture [75]. Users can translate texts into their own language using only their phone cameras, and it is particularly valuable for providing visually impaired users with the ability to read through auditory feedback [76]. In the studies conducted, it has been announced that it has a high success rate in multilingual text recognition and is one of the most successful areas where AI is used for human–computer interaction [77].

(d) **AI for Semantic Communications**: The paradigm shift in how data is transmitted and interpreted across networks is represented by semantic communication [78]. Semantic communication aims to increase bandwidth utilization and robustness compared to traditional systems. AI is critical in this area because it enables real-time contextual understanding and intent prediction. For example, transducer-based models can be used to make communication systems more human-like and context-adaptive.

(e) **AI for Cyber-Physical Systems (CPS)**: Cyber-Physical Systems (CPS) are about the integration of all computational, networking, and physical processes. In particular, they serve as the foundation for smart manufacturing and robotics. AI can enhance CPS by enabling intelligent decision-making processes such as predictive maintenance [22].

7. Emerging trends and societal impacts

As AI advancements continue rapidly, new paradigms and their societal impacts expand daily. This section examines emerging trends in AI and their impact on social, economic, and cultural systems.

1. **Emerging Trends**: It is expected that AI will expand its usage area by integrating with some developing technologies in the near future. The most important of these areas are to be briefly summarized:
2. **AI in Quantum Computing**: In the near future, quantum computers with high processing power and speed capacity are expected to enter our lives [43,79]. It is expected that these computers will solve the most complex problems that today's processors (computers) cannot solve in a very short time [80]. If computers with such high capacity are combined with AI, it is expected that the training time of AI models with very high data will be shortened and more optimized performances will be achieved [81].
3. **Advanced AI Models**: It is a known fact that AI works by imitating the human brain (neural networks) [82]. Advances in AI models, especially in biological systems, will lead to a better understanding of the way the brain works and the development of AI models in parallel [83].
4. **AI's Interaction with the Human Brain**: Recent research and technical advances that enable the human brain to communicate with chips (Neuralink project, etc.) indicate that the human brain will be able to work integrated with AI in the near future [84]. With this development, great convenience can be expected for Alzheimer's and paralyzed patients [85].
5. **Societal Impacts**: AI developments also have a major impact on social events and individuals. While AI has a negative impact on the job market, including the loss of some professions such as call centers, it also offers new job opportunities, such as data analysis. It also makes it easier for governments to develop and implement policies in areas such as urban planning and health [86]. On the other hand, it should not be forgotten that international regulations are needed for the ethical use of AI.

8. Challenges and future research directions

Despite advances in AI, scalability, generalizability, fairness, transparency, and ethical issues remain challenges. This section summarizes current technical and philosophical hurdles and highlights new areas for future research.

1. **Research Challenges**: Although AI is a revolutionary development in terms of technology and sociology, it still brings with it challenges that need to be solved. These challenges can be summarized under the following three headings.

   (a) **Ethical Issues in AI**: AI brings with it issues regarding bias and justice stemming from its algorithms. An example of this is the application Rekognition (Amazon) identifying white men with higher accuracy than black men in facial recognition [87]. Similarly, the situations where women are more disadvantaged than men in recruitment practices reveal the importance of this problem.

   (b) **Privacy Issues in AI**: AI also includes many applications that process private information (such as biometric data) [27]. Applications such as Google and TikTok offering personalized ads, and surveillance systems used in China to control social events are examples of privacy issues [88,89].

   (c) **Energy Issues in AI**: AI models with big data and complex learning algorithms (like DL) bring high energy consumption [90]. Since high energy also means high carbon emissions, AI models that consume less energy can be created.

   (d) **Generalization Issues**: DL models generally perform well within the data distribution they were trained on, and make mistakes when the data is out-of-distribution [91].

   (e) **Explainability Limitation**: LLMs cannot clearly and explicitly explain how they get their results (their decisions and answers) in a human-understandable way [92].

   (f) **Data Dependency**: The ability and biases of AI models are directly dependent on the quality of the training data. And it is not possible to provide large and high-quality data for every sector [93].

2. **Theoretical Gaps and Future Paradigms**: Although AI has grown rapidly and made great advances in technology, it still has fundamental theoretical gaps. This section discusses these theoretical gaps and the future paradigms that will shape AI.

(a) **Neuro-Symbolic AI and the Limits of Deep Learning**: Although DL has made great progress in a wide range of areas, it still has limitations in abstract thought processes such as symbolic reasoning. One of the main reasons for these limitations is that DL models learn statistical correlations rather than causal structures and fail in fragile environments [94]. Studies in the field of Neuro-Symbolic AI aim to bridge this gap by combining neural network reasoning frameworks. However, this field of study is still in its infancy, and theoretical research on the integration of subsymbolic representations and symbolic abstractions is needed.

(b) **Theoretical Challenges in Explainable AI (XAI)**: XAI is one of the recent developments frequently used in modern AI applications. Although great progress has been made in producing AI-based explanations/contents such as saliency maps, there are still theoretical limitations that need to be resolved [95]. Current XAI models attempt to explain the "what" rather than the "why" of AI-based processes. Therefore, developing AI systems that can provide theoretical explanations about causality by reasoning naturally remains a major challenge.

(c) **Brain-AI Interfaces and New Learning Models**: Developments such as Neuralink, which aim to provide communication between the human brain and AI, have made a big impact. The background of these developments is the collection of real-time bioelectric signals and their processing in compatible learning models. Traditional supervised and unsupervised methods are inadequate in these systems [96]. For this reason, new theoretical models are needed to understand how biological and AI systems can work together.

(d) **Towards a Unified Theory of Intelligence**: Despite major advances in the field of AI, there is still no unified theory to explain natural and artificial intelligence. Theories/studies that integrate memory, emotion, and consciousness are expected to become widespread in the near future, and AGI applications are expected to expand in light of these developments [97]. This theory will need to cover a wide range of fields, such as computer science, neuroscience, cognitive psychology, and be compatible with human values and ethical standards.

3. **Ethical and Privacy Challenges**: AI brings with it issues regarding bias and justice stemming from its algorithms. An example of this is the application Rekognition (Amazon) identifying white men with higher accuracy than black men in facial recognition [87]. Similarly, the situations where women are more disadvantaged than men in recruitment practices reveal the importance of this problem.

9. Summary and conclusions

Artificial Intelligence (AI) is one of the most important technological developments, which is impacting many areas, from daily life to scientific developments. Despite all the advantages it offers, AI still brings with it challenges such as privacy and high energy consumption. In order for AI to be used more actively, researchers and leading companies in the sector should develop solutions to these problems. In addition, promising developments in the fields of quantum computing and neuroscience show that AI has great potential in the near future. As a technology that shapes the future, AI should take into account social values such as ethics and justice, and should be integrated into human life within internationally determined policies for more effective use. This paper examines the historical development, basic principles, and current trends of artificial intelligence, which is used effectively in various civil and military areas. It also aims to provide insight to the reader by examining the developing sub-branches of AI, such as Machine Learning (ML), Deep Learning (DL), and Natural Language Processing (NLP).

CRediT authorship contribution statement

Muhammed Golec: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation. **Emir Sahin Hatay:** Writing – review & editing, Writing – original draft, Visualization, Formal analysis, Data curation. **Sukhpal Singh Gill:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Investigation, Formal analysis, Conceptualization. **Rajkumar Buyya:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Methodology, Investigation, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

We thank the Editor-in-Chief (Prof. Ke Xue), Associate Editors (Prof. Mingxin Zhang and Prof. Jianxun Chu) and anonymous reviewers for their insightful comments and recommendations to improve the overall quality and organization of the article. The final revision of this work is carried out by the first author at Boğaziçi University.

Data availability

No data was used for the research described in the article.

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Muhammed Golec has received his Ph.D. in the School of Electronic Engineering and Computer Science at Queen Mary University of London (QMUL), where he also completed his M.Sc. in Computer Science (Distinction) through the Ministry of Education Scholarship. Recently, he has joined the Department of Computer Engineering at Boğaziçi University as an Assistant Professor. He has published articles in prominent journals and conferences such as IEEE TII, IEEE IoT, Elsevier IoT, IEEE Consumer Electronics Magazine, IEEE TSUSC, and IEEE CCGRID. His research interests include Cloud Computing, Serverless Computing, Artificial Intelligence (AI), and Security and Privacy. For more information, please visit muhammedgolec.com.

Emir Sahin Hatay is a Bachelor's Degree student in Computer Science at the University of Essex, with research interests in Artificial Intelligence and Quantum Computing. He has contributed to four international publications as an author and co-author and has experience working on AI-driven cloud applications and web projects involving both front-end and back-end technologies.

Sukhpal Singh Gill (FHEA) is an Assistant Professor of Cloud Computing at the School of Electronic Engineering and Computer Science, Queen Mary University of London, UK. Dr. Gill is serving as an Editor-in-Chief for IGI Global IJAEC and Area Editor for Springer Cluster Computing Journal, also serving as an Associate Editor in IEEE IoT, Nature Scientific Reports, Wiley SPE, Elsevier IoT, Wiley ETT, Elsevier Telematics and Informatics Reports and IET Networks Journals. He has co-authored 200+ peer-reviewed papers (with Citations 15400+ and H-index 61) and has published in prominent international journals and conferences such as IEEE TPDS, IEEE TFS, IEEE TGCN, IEEE TCC, IEEE TSC, IEEE TSUSC, IEEE COMST, IEEE TCE, ACM TOIT, ACM CSUR, ACM TAAS, IEEE TII, IEEE TNSM, IEEE IoT Journal, Elsevier JSS/FGCS, IEEE/ACM UCC and IEEE CCGRID. He has received several awards, including the Queen Mary University Education Excellence Award 2023, Outstanding Reviewer Award from IEEE IT Professional Magazine 2024, Elsevier Internet of Things Editor's Choice Award 2024, Elsevier Best Paper Award 2023, Distinguished Reviewer Award from SPE (Wiley) and Best Paper Award AusPDC at ACSW 2021. He has edited and authored research various books for Elsevier, Springer and CRC Press. His research interests include Cloud Computing, Edge Computing, IoT and Energy Efficiency. For further information, please visit: www.ssgill.me.

Rajkumar Buyya is a Redmond Barry Distinguished Professor and Director of the Quantum Cloud Computing and Distributed Systems (qCLOUDS) Laboratory, at the University of Melbourne, Australia. He is also serving as the founding CEO of Manjrasoft, a spin-off company of the University, commercializing its innovations in Cloud Computing. He served as a Future Fellow of the Australian Research Council during 2012–2016. He has authored over 850 publications and seven text books including "Mastering Cloud Computing" published by McGraw Hill. He is one of the highly cited authors in computer science and software engineering worldwide (h-index=174, g-index=371, 164000+ citations). Dr. Buyya is recognized as a "Web of Science Highly Cited Researcher" for seven times since 2016, a Fellow of IEEE and Foreign Fellow of Academia Europaea. Recently, he received "Research Innovation Award" from IEEE Technical Committee on Services Computing and "Research Impact Award" from IEEE Technical Committee on Cloud Computing. Software technologies for Grid and Cloud computing developed under Dr. Buyya's leadership have gained rapid acceptance and are in use at several academic institutions and commercial enterprises in 50+ countries around the world. He acknowledges all researchers and institutions worldwide for their consideration in building on software systems created by his CLOUDS Lab and recognizing them through citations and contributing to their further enhancements. He served as the founding Editor-in-Chief of the IEEE Transactions on Cloud Computing. He is currently serving as Co-Editor-in-Chief of Journal of Software: Practice and Experience, which was established 50+ years ago. For further information on Dr. Buyya, please visit his cyberhome: www.buyya.com.