ANALYSIS OF PRESENT AND FUTURE USE OFARTIFICIAL INTELLIGENCE (AI) IN LINE OF FOUTH INDUSTRIAL REVOLUTION (4IR)

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Abstract: Artificial Intelligence (AI) is transforming our lives, offering numerous benefits across various industries, businesses, and service sectors. The widespread adoption of AI technology is gaining momentum as organizations recognize its advantages. AI-based applications are already trending in different fields, driving digital transformation worldwide. By incorporating AI into their operations, industries and sectors can streamline processes and increase efficiency. Embracing AI in our business will allow us to harness its benefits. In essence, AI refers to the intelligence demonstrated by appliances. Many organizations, businesses, and companies are already leveraging AI to address challenges in various industries, organizations, services, sectors, and academia. Similar to electricity, machinery, equipment, and computers, AI is a versatile technology with a wide range of applications. Presently, it is utilized in fields such as language translation, image recognition, credit scoring, e-commerce, e-business, service sectors, military, air and maritime transportation, and many more domains. However, the extensive proliferation and advancement of AI also necessitate robust security measures. As AI is deployed in transportation and medical care in the coming years, it is crucial to introduce the technology in a manner that builds trust, understanding, and respects human and civil rights. .[1] Considering that we are in the early stages of the Fourth Industrial Revolution (4IR), it is evident that the future use of AI will become even more versatile and intricate. Humans will increasingly rely on AI in the future. This research paper aims to evaluate the current and future applications of AI in the context of the 4IR.

Key Words: AI, IoT, ML, Cybersecurity, 4IR, AR, VR, 3D printer, VLE, KM

Introduction

Artificial Intelligence (AI) is a broad term that encompasses computer software capable of performing humanlike activities such as learning, planning, and problem-solving. It is a multifaceted field of computer science that focuses on creating intelligent machines capable of executing tasks typically associated with human intelligence.[2] AI incorporates various disciplines, including computer science, data analytics, statistics, hardware and software engineering, linguistics, neuroscience, philosophy, and psychology.[3] AI can be categorized into five main components: Reasoning, Learning, Problem Solving, Perception, and Linguistic Intelligence.[4] Today, AI has evolved into an interdisciplinary science, and advancements in machine learning and deep learning have led to a significant transformation across the technology industry.[5] AI is a collection of technologies that empower computers to perform complex functions, such as visual perception, natural language understanding, translation, data analysis, and recommendation systems. Presently, AI serves as a fundamental driver of innovation in modern computing, delivering value to individuals and businesses[6] alike. While referring to specific applications as AI is technically accurate, it is similar to calling a car a "vehicle" without considering its specific[7] features. To comprehend the prevalent types of AI in business, services, industries, and our personal lives, a deeper understanding is required. Machine Learning (ML) is one of the most prominent forms of AI employed in contemporary business settings. It focuses on processing large volumes of data efficiently. Machine learning algorithms have the ability to "learn" from data, improving their models over time.[8] This technology is particularly useful for extracting meaningful insights from vast amounts of data generated by connected devices and the Internet of Things (IoT). For instance, in a manufacturing plant, connected devices continuously transmit data regarding functionality and production. Due to the sheer volume, it is impractical for humans to manually analyze this data comprehensively, resulting in potential pattern recognition limitations.

Robotics, a subset of AI, focuses on various branches and applications of robots. AI robots are artificial agents that operate in real-world environments, taking responsible actions.[9] to achieve desired outcomes. Expert systems, which are AI-based computer systems, emulate the decision-making capabilities of human experts. These systems employ if-then logical statements to solve complex problems, diverging from traditional procedural programming approaches. Expert systems find applications in information management, medical facilities, loan analysis, virus detection, and more. The advancement of AI technology has facilitated instantaneous language comprehension, as exemplified by ChatGPT certification courses available online. AI research has also led to the development of tools for representing specific domains, including objects, properties, categories, object relationships, [10] situations, events, states, time[11], causes and effects, [12] knowledge about knowledge (i.e., knowledge about what others know), [13] default reasoning (i.e., assumptions that remain true until proven otherwise, even as other facts change), [14] and more. Tasks such as speech or image recognition can be performed significantly faster by AI systems compared to manual identification by human experts. Among the well-known neural networks, Google's search algorithm[15] stands out as an example.

Intelligence refers to a system's capacity to perform calculations, reasoning, perceive relationships and analogies, learn from experience, store and retrieve information from memory, solve problems, comprehend complex concepts, fluently use natural language, classify, generalize, and adapt to new situations. Intelligence is an intangible[16] attribute. Machine Learning (ML) is the scientific field focused on enabling machines to interpret, process, and analyze data in order to address real-world problems. [17] On the other hand, Deep Learning involves implementing Neural Networks on high-dimensional data to gain insights and formulate solutions. [18] Deep Learning represents an advanced area within Machine Learning that can tackle more complex problems. Natural Language Processing (NLP) pertains to the discipline of extracting insights from human language to facilitate communication with machines and drive business growth. [19] ML enables rapid analysis of incoming data, detecting patterns and anomalies. For instance, if a machine in a manufacturing plant is operating at reduced capacity, a machine-learning algorithm can identify the issue and alert decision-makers to dispatch a preventive maintenance team. However, ML encompasses a broad range of techniques. The development of artificial neural networks, forming interconnected nodes within AI systems, has led to the emergence of deep learning. [20] ML is frequently applied in systems that capture substantial amounts of data. For instance, smart energy management systems collect sensor data from various assets, and machine-learning algorithms contextualize this data, providing insights to decision-makers for better understanding energy usage and maintenance needs. The rapid advancement of AI technology and machine learning is driving significant transformations across global business, industries, and service sectors, laying the groundwork for an AI-driven future. It is crucial to carefully and judiciously analyze[21] expert opinions and commentary on the benefits and risks, the implications for companies, workers, and consumers, and the potential impacts on various technology markets.

Artificial Intelligence (AI) has been rapidly advancing and shows no signs of decelerating. Presently, AI permeates nearly all aspects of our lives. It is an interdisciplinary field of computer science dedicated to the development of intelligent machines capable of performing complex tasks, including those that traditionally require human intelligence. AI employs various approaches, such as Machine Learning (ML) and deep learning, to simplify and enhance task completion. The significant advancements in these capabilities have resulted in a transformative shift across almost every sector. In the future, the use of AI will enable companies to accelerate the process of drug discovery. AI will enhance the detection of life-threatening diseases like cancer, diabetes, and neurological disorders, enabling earlier and more accurate diagnoses than ever before. Furthermore, AI will expedite drug discovery and clinical trials, reducing healthcare costs and the time required to bring new drugs[22] to market. The overall research and development (R&D) spending in the pharmaceutical industry is projected to reach approximately $204 billion by 2024. For instance, in drug discovery, pharmaceutical companies can leverage machine learning techniques and natural language processing (NLP) to analyze academic literature and journal publications, identifying promising compounds for experimentation. Currently, the development of new materials can take an average of 20 years from ideation to implementation. However, with the aid of AI, the materials development process can be accelerated, granting R&D teams, including those within biopharmaceutical organizations, more time and boosting research productivity significantly.

AI's impact on technology stems from its profound influence on computing. By leveraging AI, computers can effectively process vast amounts of data and utilize learned intelligence to make optimal decisions and discoveries in significantly less time than humans. [23] However, the introduction of AI also brings forth complex challenges in several key areas that will shape the future of the digital age. These areas include the justice system, the impact on democracy, global security and international conflicts, the effects of automation on the job marketplace, identity, and privacy. Presently, AI has become indispensable in operating, managing, and executing daily tasks, extending its reach across all industries, businesses, and service sectors. In the future, our reliance on AI is expected to grow even further. [24] As we move into the era of the Fourth Industrial Revolution (4IR), AI will undoubtedly exert a significant influence on every aspect of our lives. The integration of enabling technologies within the manufacturing supply chain is envisioned to enhance Industry 4.0. To assess the current and future utilization of AI in the context of the 4IR, this research paper conducts a systematic

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literature review, synthesizing information[25] from limited primary sources and extensive secondary sources. The aim is to present a simplified overview of this complex subject matter.

Figure 1: AI has brought the world in our finger tips[26] and future of AI[27]

AI Domains

AI refers to the intelligence exhibited by machines, involving the perception, synthesis, and inference of information, distinct from the intelligence displayed by humans or other animals. In the late 1980s and 1990s, AI research advanced methodologies to handle uncertain or incomplete information, incorporating principles from probability and economics. However, human problem-solving predominantly relies on rapid, intuitive judgments, rather than the step-by-step deduction that early AI research aimed to model. Intelligent personal assistants utilize AI to comprehend natural language requests through various means, moving beyond basic commands. ML-related issues in 5G and future networks[28] present opportunities for new research areas and expansions of existing standards to support forthcoming network developments. Essentially, AI refers to the intelligence demonstrated by machines. The domain of AI encompasses a vast scope, spanning breadth and depth. [29] Humans perceive information through patterns, whereas machines rely on sets of rules and data for perception. Humans store and recall information based on patterns, while machines utilize searching algorithms. For example, humans can recognize a complete object even if parts are missing or distorted, whereas machines may struggle to do so accurately. Since its emergence on the global stage in 2009, AI domains have gained increasing popularity. [30] There are several reasons for this, and it is likely that one or more of these factors apply to our business. AI domains are typically more affordable than their ".com" counterparts. [31] There are few important AI domains as described below:

Machine Learning. Machine learning (ML) is a subset of artificial intelligence that enables machines to learn automatically from data without explicit programming. Its primary objective is to develop algorithms capable of recognizing patterns and relationships within data, leveraging these insights for predictions or decisions. ML can be classified into three key categories: supervised learning, unsupervised learning, and reinforcement learning. In supervised learning, algorithms are trained using labeled data, where both input and output variables are known. The aim is to learn a mapping function that can predict output variables for new inputs. Unsupervised learning involves training algorithms on unlabeled data, where only the input variables are provided. The objective here is to discover the underlying data structure, such as clusters or patterns. In reinforcement learning, algorithms learn by interacting with an environment, receiving rewards or penalties based on their actions. [32] Typical ML algorithms comprise three core elements: a model, an objective function, and an optimization algorithm. The model serves as a mathematical representation of the problem the algorithm addresses. The objective function measures the model's performance on the task at hand, and the optimization algorithm adjusts the model's parameters to minimize the objective function. [33]

Training a machine learning (ML) model involves providing it with a vast amount of data and adjusting its parameters until it can accurately predict the output for new inputs. Once trained, the model can be utilized to make predictions on unseen data. ML has gained significant importance in the realm of artificial intelligence, driven by the exponential growth of data and the imperative to derive meaning from it. ML algorithms find applications across various domains, including image recognition, natural language processing, self-driving cars, and personalized medicine. A notable advantage of ML is its ability to automate tasks that are challenging or impractical for humans to perform manually. For instance, ML algorithms can analyze extensive medical data to identify patterns that aid in developing more effective disease treatments. They can also detect financial transaction fraud or optimize supply chain operations. ML serves as a crucial aspect of AI, enabling computers to learn from data and make informed predictions or decisions. As the demand for automation and the volume of data continue to surge, ML has become an indispensable tool across diverse applications. With the ongoing evolution of AI, ML is poised to assume an increasingly significant role in shaping the future of technology.

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Deep Learning. Deep learning, a captivating subset of machine learning, stands out as one of the most remarkable domains within the field of AI today. It revolves around training algorithms to learn from extensive data and make informed decisions based on that knowledge. Deep learning is renowned for its exceptional capacity to accurately identify patterns within data and employ those patterns to make predictions. This article aims to delve into the fundamental aspects of deep learning and its profound significance in the realm of AI. The concept of deep learning draws inspiration from the intricate workings of the human brain. Similar to how neurons in our brains connect to process information, deep learning algorithms employ artificial neural networks to analyze data. These networks consist of multiple layers of interconnected nodes, with each node receiving input from the preceding layer, processing it, and transmitting it to the subsequent layer. This iterative process persists until the algorithm reaches a final output layer, which yields the desired outcome. [34]

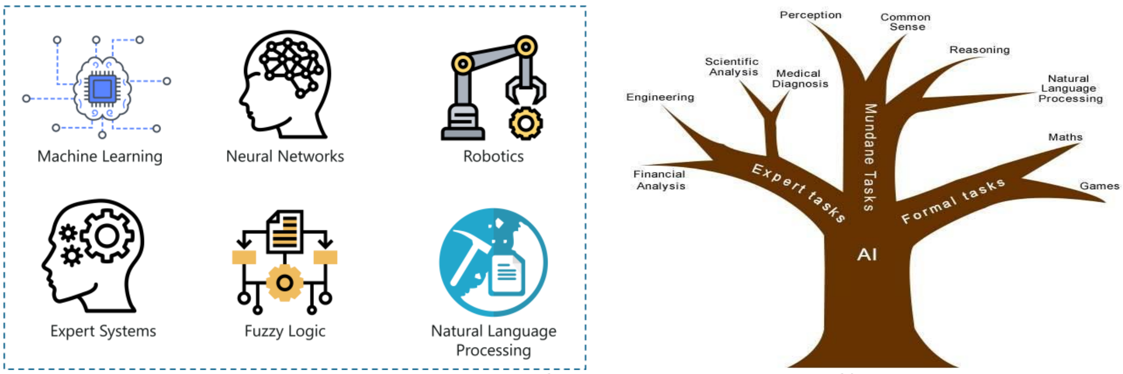

Figure 2: Domains of AI[35] and Types and task of AI[36]

An inherent advantage of deep learning lies in its capability to autonomously extract features from unprocessed data. This implies that deep learning algorithms possess the ability to discern and comprehend patterns and structures within the data without explicit programming. For instance, a deep learning algorithm trained on an image dataset can automatically acquire the capacity to identify various objects, even those it has not encountered previously. Deep learning finds diverse practical applications across numerous fields, including computer vision, speech recognition, natural language processing, and robotics. Within computer vision, deep learning algorithms are employed to scrutinize images and videos, detect objects, and recognize faces. In speech recognition, deep learning algorithms transcribe speech into text, while in natural language processing, they analyze and comprehend human language. The triumph of deep learning can be attributed to the abundance of vast data, potent computing resources, and advancements in algorithmic development. With the escalating availability of data, deep learning algorithms are becoming increasingly accurate and sophisticated. Simultaneously, the advent of specialized hardware like Graphics Processing Units (GPUs) has empowered researchers to train deep learning algorithms with enhanced speed and efficiency. [37]

Natural Language Processing. Natural Language Processing (NLP) constitutes an AI domain dedicated to equipping computers with the ability to comprehend, interpret, and generate human language. NLP serves as a subfield of AI that focuses on the interaction between computers and human linguistic expressions. Essentially, NLP involves the manipulation and analysis of raw language employed by humans for communication purposes. Within NLP, human language is segmented to facilitate the examination and comprehension of sentence structure and the significance of individual terms within their respective contexts. The objective of an NLP-powered model is to possess the competence to "understand" document scopes, encompassing factors such as slang usage, irony, underlying meanings, and contextual nuances specific to the language employed in the text. Accomplishing this entails employing algorithms, statistical models, and machine learning techniques to analyze and extract meaning from human language data.NLP has several subfields that are used for different applications, including:

- Text Processing: This entails utilizing algorithms to extract and cleanse textual data from various sources, including documents, social media platforms, and websites.
- Text Analysis: This involves employing algorithms to identify patterns, relationships, and sentiments within text data.
- Speech Recognition: This utilizes algorithms to convert spoken language into written text format.
- Machine Translation: NLP can be employed to translate text from one language to another, proving valuable in international business and communication.
- Natural Language Generation: NLP can be leveraged to develop chatbots and virtual assistants capable of understanding and responding to natural language queries. It entails utilizing algorithms to generate human-like text, commonly used for chatbots, virtual assistants, and automated content creation.
- Sentiment Analysis: NLP can be utilized to analyze customer reviews and social media posts to determine the sentiment expressed by the writer.

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- Content Creation: NLP can be employed to automatically generate content, such as news articles and product descriptions.

Computer Vision. Computer vision, an artificial intelligence (AI) domain, focuses on enabling machines to comprehend and interpret visual information from their surroundings. It encompasses the utilization of algorithms and mathematical models to analyze, interpret, and process visual data, finding applications across diverse industries. Recent years have witnessed significant advancements in the field of computer vision, particularly with the emergence of deep learning techniques and the availability of extensive datasets. These advancements have empowered machines to recognize objects, detect patterns, and make informed decisions based on visual information.[38] Notably, computer vision plays a vital role in the realm of autonomous vehicles. Self-driving cars heavily rely on computer vision technology to interpret data from sensors such as cameras, LiDAR, and radar, enabling safe and efficient navigation on the roads. In the manufacturing industry, computer vision is employed to detect defects in products and ensure quality control. Furthermore, computer vision finds significant applications in the healthcare sector. Medical professionals utilize computer vision algorithms to analyze medical images, such as X-rays, CT scans, and MRIs, aiding in the diagnosis of various medical conditions. Additionally, computer vision technology plays a role in drug discovery by enabling researchers to analyze and interpret extensive datasets to identify potential drug candidates.

Computer vision finds applications in the retail industry as well, where it enables the tracking of customer behavior and offers personalized recommendations based on individual preferences. This technology also plays a crucial role in security systems, allowing for the detection of suspicious activities and prevention of crimes. The progress of computer vision can be attributed to advancements in machine learning and deep learning techniques, empowering machines to identify patterns and features within images. Convolutional Neural Networks (CNNs) are particularly popular in computer vision, as they can analyze images at multiple levels and identify essential features for object recognition. Despite remarkable advancements, challenges still exist in the field of computer vision. One primary challenge involves developing algorithms that can handle variations in lighting conditions, occlusions, and other factors affecting image quality. Another challenge is creating algorithms that are interpretable and transparent, especially for critical applications such as healthcare and autonomous vehicles. In conclusion, computer vision, as a domain of artificial intelligence, offers diverse applications across industries. Its capability to interpret and analyze visual data allows machines to make informed decisions based on visual information, potentially revolutionizing numerous fields. As machine learning and deep learning techniques continue to advance, computer vision will undoubtedly maintain its significant role in the progression of AI.

Data Science. The field of data science, which has rapidly evolved in recent years, has become an indispensable domain within AI. Data science revolves around extracting insights, knowledge, and information from extensive and intricate datasets using advanced analytical and statistical tools. This process entails cleaning, transforming, analyzing, and interpreting data to derive meaningful conclusions that inform business and organizational decisions. As AI continues to permeate various sectors, data science assumes an increasingly critical role within the technology industry.[39] Machine learning stands out as a fundamental aspect of data science, involving the utilization of algorithms to uncover patterns in data and construct models capable of predicting future outcomes. Machine learning has become an essential component of AI, finding application in a diverse range of areas, including speech recognition, image classification, fraud detection, and natural language processing. Machine learning models are designed to learn from data, refining their accuracy over time as they process more information.

Data visualization stands as another significant facet of data science. It serves as a potent tool for effectively conveying intricate data insights to non-technical stakeholders. Data visualization involves creating interactive and captivating graphics that aid decision-makers in comprehending complex datasets more readily. Within data science, data visualization holds crucial importance, as it enables stakeholders to swiftly identify trends, anomalies, and patterns within extensive data sets. The field of data science extends beyond machine learning and data visualization, encompassing a diverse range of tools and techniques. These include statistical modeling, data mining, and data engineering, among others. These tools are utilized for data preprocessing, pattern identification, statistical analysis, and model development, all of which contribute to informed decision-making.[40]

AI is the Driver for Forth Industrial Revolution (4IR)

The Fourth Industrial Revolution (4IR) brings forth novel ways in which technology becomes deeply intertwined not only with society, the economy, and culture, but also with the human body and mind. At the forefront of this digital transformation, driven by cyber-physical systems, lies Industry 4.0. This term refers to recent technological advancements wherein the internet, along with supporting technologies and embedded systems, forms the foundation for integrating physical objects, human agents, intelligent machines, production lines, and processes across organizational boundaries. The result is the creation of a new kind of intelligent and

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networked value chain known as the smart factory. [41] In essence, 4IR encompasses both the economic aspect of a "broader restructuring" of the modern economy and society, as well as the technological aspect rooted in computer science and information science, involving advancements in pervasive computing, algorithms, and artificial intelligence. [42]

In 2016, during the World Economic Forum, Mr. Klaus Schwab, the executive chairman, introduced the concept of the "second machine age" as a central theme of the Fourth Industrial Revolution (4IR). This term encompasses the impact of digitization, artificial intelligence, as well as advancements in nano and bio-technologies, on the global economy. What sets 4IR apart from previous industrial revolutions is the convergence and interplay of these technologies across physical, biological, and digital domains. This convergence is leading to significant disruptions in traditional manufacturing and transportation paradigms, with advanced robotics and autonomous vehicles leveraging cloud-based information access. Moreover, artificial intelligence is revolutionizing processes across various industries and institutions, transforming the way individuals and organizations engage and collaborate. Additionally, 3D printing is reshaping manufacturing by enabling the creation of physical objects from digital designs using innovative materials, while advancements in nano and bio-technologies are blurring the boundaries between digital, physical, and biological realms.

The advent of the Internet, sensors, and embedded systems has created a novel environment where the convergence of physical, mechanical, mental, and digital work is becoming possible. This convergence is facilitated by the latest phase of pervasive computing, which involves the progressive integration of Information Technology (IT) and Operational Technology (OT). Pervasive computing combines two historically distinct economic developments: the advancements in Information Technology, encompassing business process automation, office automation, predictive data analytics, and the rise of smartphones and administrative automation, with Operational Technology, which focuses on industrial machinery and automation that originated during the industrial revolution. This integration leads to further industrial development centered around end-to-end automation, with three key paradigms: machine-to-machine communication (M2M) not only within factories but also across all conceivable devices and systems, predictive maintenance of machines and appliances based on direct status reports for potential upgrades and remote repairs, and improved human-to-machine interaction (H2M) primarily through the usage of consumer products that share user data with appliances to create new value and enhance service quality. At the forefront of this described digital transformation, powered by cyber-physical systems, stands Industry 4.0. This term refers to recent technological advancements where the internet, along with supporting technologies or embedded systems, serves as the foundation for integrating physical objects, human actors, intelligent machines, production lines, and processes across organizational boundaries. This integration gives rise to a new kind of intelligent, networked, and agile value chain known as the smart factory. [43]

At its core, Industry 4.0 represents the movement towards automation and data exchange within manufacturing processes, supported by Information and Communication Technology (ICT) tools such as cyber-physical systems (CPS), cloud computing, cognitive computing, big data analytics, artificial intelligence (AI), and the Industrial Internet of Things (IIoT). This transformation is guided by three key principles: interconnectivity and information transparency, technical assistance, and decentralized decision-making. These principles apply not only horizontally across different systems but also vertically across all levels of automation, enabling integrated and networked factories, machines, and products to operate intelligently and partially autonomously, with minimal intervention required from humans, both in terms of physical and cognitive involvement. [44] If we look at the ongoing Industrial Revolution from the perspective of development of cyber-physical systems, using web metaphor to describe the world after ICT revolution, four steps come into view[45]:

- Web 1.0: This phase represents the read-only web, with a primary focus on companies and providing connected information through static home pages.
- Web 2.0: This phase signifies the transition to a read-write web, with a strong community focus that connects people through interactive platforms such as blogs and wikis.
- Web 3.0: This phase introduces the concept of read-write-execute, with an individual focus that connects knowledge through live-streams, intelligent agents, and semantic webs.
- Web 4.0: This phase encompasses the read-write-execute concurrency web, emphasizing the connection of intelligence through a symbiotic web, where humans and machines converge in knowledge networks.

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Web 3.0, also referred to as the semantic web, offers a structured approach to data, facilitating efficient linking of existing systems for reuse across various applications. This enables the creation of context, providing meaning to data through the use of metadata. Software agents[46] can then locate, evaluate, and deliver this meaningful information. The next evolution, Web 4.0, is characterized as the symbiotic and ubiquitous web, also known as the intelligent web. It revolves around a symbiotic relationship between humans and machines, with the entire web functioning as a unified operating system that interacts and communicates with users, acting as a personal assistant. [47] It is evident that the progression through these stages of the web depends on two factors: the degree of information connectivity, driven by technological advancements and digital disruption, and the degree of social connectivity, involving active user involvement and social interactions. [48]

The term "ambient intelligence" describes an electronic environment that is aware of and responsive to the presence of individuals. In this environment, devices collaborate to support people in their everyday activities, tasks, and routines in a natural manner. This is achieved by leveraging the information and intelligence available through the network connecting these devices. Originally coined by Eli Zelkha and his team at Palo Alto Ventures, the term was used to describe a computing paradigm that shifted from an explicit, instructional model to an implicit, anticipatory one. This new model incorporates context-awareness, personalization, adaptability, and anticipatory machine intelligence.

Fifth Generation (5G) Technology refers to the next generation of communication technology, succeeding the 4G technology. 5G is built upon Long Term Evolution (LTE) and offers advanced data capacity with data transmission speeds of up to 100 megabits per second (Mbps), which is about ten times faster than the speeds provided by 3G. While the initial specifications of 5G extend up to 1 gigabit per second (Gbps), actual speeds range from 600 Mbps up to 2.5 Gbps, making it significantly faster than 4G (10 to 100 times faster). This enables real-time functionality for devices and applications connected to the Internet of Things (IoT). The concept of IoT is closely intertwined with advancements in 5G technology and artificial intelligence. [49] It involves a large-scale network of intelligent systems[50] comprising multiple agents, capable of handling data transmission and sharing between machines (M2M). The performance of the entire system greatly depends on these capabilities.

It is inherent in human nature to desire connection, and as such, we are increasingly adapting to the interconnected environment. This transition entails moving from primarily local and physical connectivity to a globally interconnected digital environment characterized by rapid connectivity. This shift is reshaping our communication patterns and transforming the way we live, work, and interact with one another. Technology plays a mediating role, facilitating fast data transfers and the exchange of information. Currently, we find ourselves living in an "onlife in infosphere" state, where pervasive connectivity is becoming more synchronized, delocalized, and interconnected. This marks the fourth progressive process of informationalization and digitalization, permeating almost every aspect of our lives. Consequently, we are witnessing a growing dependence on and anthropomorphization of both objects and technologies. These changes have profoundly impacted our perception of ourselves and the world, transitioning from a modern, historical, and materialistic viewpoint to a postmodern, hyperhistoric, and informational perspective. The industrial revolution previously marked a shift from a world of unique objects to a world of reproducible object types through mass production, rendering identical objects replaceable without any loss.

The post-industrial or digital revolution, including subsequent stages such as the Fourth Industrial Revolution (4IR) and the Internet of Things (IoT), signifies a transition from a world predominantly focused on physical objects and processes to a digital realm where objects and processes are virtualized. [51] This transition intensifies the ongoing transformation. The digital "proxy" culture not only removes physicality but also diminishes our individuality by primarily categorizing us as consumers, defining our work, purchases, and the type of information we consume (such as metadata or big data). Consequently, our sense of personal identity erodes as we perceive ourselves as anonymous entities among billions of similar individuals online. Furthermore, this transformation brings about significant changes in economic and social perceptions of goods and services. [52] Alongside these changes emerges the "digital divide," which leads to widespread discrimination based on generational gaps, geographical disparities, socio-economic differences, and cultural variations. This divide permeates across all societies and nations, separating individuals into the categories of "information-rich insiders" and "information-poor outsiders" who either reside within or outside the realm of the information sphere. [53]

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In the era of the Fourth Industrial Revolution (4IR), artificial intelligence (AI) has emerged as a highly important and significant subject of study due to its versatility, spanning multiple disciplines, dimensions, and organizations. According to Nel and Masilela, innovation is widely acknowledged as a crucial driver of economic growth, development, entrepreneurship, the creation of new products and services, market expansion, enhanced organizational efficiency, and the delivery of public value in academic, professional, public, and private sectors such as economics, engineering, science, sociology, and institutions.[54] Ndung'u and Signe affirm that the 4IR is characterized by the integration of the digital, biological, and physical realms. The increasing adoption of new technologies like AI, cloud computing, robotics, 3D printing, the Internet of Things (IoT), and advanced wireless technologies has ushered in a new era of governance.[55]

Present Uses of AI

AI has found applications in a wide range of sectors, including smart machines, industrial automation, agriculture, healthcare, transportation, ecosystems, warfare, business, education, and many others. Its potential to transform our lives is remarkable, enabling smarter, more connected, flexible, efficient, and even unimaginable systems. AI has the capacity to enhance industry efficiency, increase productivity, and significantly improve our daily lives across a limitless spectrum. Virtually any intellectual task[56] can benefit from AI. The number of modern AI techniques is extensive and continually expanding.[57] Interestingly, once a technique becomes widely adopted, it tends to no longer be considered AI, a phenomenon referred to as the AI effect.[58] Throughout the 2010s, AI applications played a central role in the most commercially successful areas of computing and have become an omnipresent feature of our daily lives. Examples include their use in search engines like Google and Yahoo, targeted online advertisements,[59] recommendation systems by platforms like Netflix, YouTube, and Amazon, driving internet traffic,[60] targeted advertising through platforms like AdSense and Facebook, virtual assistants such as Siri and Alexa,[61] autonomous vehicles including drones, ADAS, and self-driving cars, automatic language translation services like Microsoft Translator and Google Translate, facial recognition technologies like Apple's Face ID and Microsoft's DeepFace, image labeling used by platforms like Facebook, Apple's iPhoto, and TikTok, spam filtering, and chatbots like ChatGPT.

Throughout the course of human history, spanning from the Paleolithic Age to the Fourth Industrial Revolution (4IR), materials have played a significant role. Material science aims to investigate the interplay between the structure, processing, properties, and applications of materials.[62] The discovery of new materials holds tremendous potential for advancing human society. Over the past few decades, AI has garnered widespread attention due to its capacity to enhance automation and accelerate productivity.[63] Recent advancements, such as the availability of extensive training data, improved computational power, and advanced deep learning algorithms, have facilitated the broad application of AI, including in the field of material research. The conventional trial-and-error approach to studying materials is both inefficient and time-consuming. Therefore, AI, particularly machine learning, can expedite the process by learning patterns from datasets and constructing predictive models.[64] This stands in stark contrast to computational chemistry, where computers serve as calculators executing predetermined formulas provided by human experts. An unsupervised ML program[65] called Atom2Vec has demonstrated its ability to reconstruct the periodic table of elements within a few hours. Atom2Vec initially learns to differentiate between different atoms by analyzing a list of compounds in an online database.[66]

The findings demonstrate that the efficiency of identifying potential new materials using the AI-based modified MATLAB model is three times higher than random guessing and twice as high as that achieved by Stanford graduate students working in related fields.[67] Machine learning (ML) training data can be derived not only from experimental tests but also from high-throughput simulations.[68] From the perspective of computer scientists, a chemical reaction can be represented as a set of data that indicates the connections or relationships among compounds,[69] often expressed as a structured format like a graph or network.[70] AI can then leverage this structural data to guide the synthesis route.[71] In traditional material development processes, a multitude of parameters require manual analysis and adjustment in synthesis, processing, and device assembly. ML possesses powerful nonlinear regression capabilities, enabling it to navigate the vast parameter space and identify optimal settings. With the advancement of the Material Genome Project, the combination of high-throughput materials preparation, analysis, and AI-driven approaches becomes inevitable.[72] The future of material informatics relies on conducting high-throughput experiments, simulations, and characterization, harnessing the full potential of advanced AI.[73],[74],[75] Therefore, AI will not entirely replace humans in material research but rather serve as a powerful tool to expedite the progress of materials discovery.[76]

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AI has the potential to generate datasets of spectral signatures for molecules involved in the atmospheric production or consumption of specific chemicals, such as phosphine, which was possibly detected on Venus. This application can help prevent misassignments and, with improved accuracy, aid in future detections and identifications of molecules on other planets. [77] ML can contribute to the restoration and attribution of ancient texts, [78] facilitating tasks like indexing to enable more effective searching[79] and classification of fragments. [80] Additionally, AI can be employed to investigate genomes and unveil genetic history, such as interbreeding between archaic and modern humans, leading to the inference[81] of the existence of a "ghost population" distinct from Neanderthals or Denisovans. It can also enable non-invasive and non-destructive access to the internal structures of archaeological remains. [82] In an unpublished approach inspired by studies of visual cognition in infants, [83] a deep learning system was reported to learn intuitive physics from visual data in virtual 3D environments. Other researchers have developed ML algorithms capable of discovering fundamental variables in various physical systems and predicting their future dynamics based on video recordings of their behavior. In the future, such algorithms may automate the discovery of physical laws governing complex systems. [84]

AI finds application in materials optimization and discovery, including the identification of stable materials and the prediction of their crystal structures. [85] ML is utilized in diverse forms of reverse engineering, such as the unauthorized production of high-quality parts[86] by reverse engineering composite material components and rapid comprehension of malware[87] behavior. It can also reverse engineer artificial intelligence models[88] and design components, such as inverse molecular design for desired functionality[89] or protein design for specific functional sites, by engaging in virtual reverse engineering. Reverse engineering of biological networks can model interactions in a human-understandable manner, leveraging time series data of gene expression levels. [90]

AI plays a central role in law-related professions, with algorithms and machine learning assuming tasks previously carried out by entry-level lawyers. [91] However, while its use is widespread, it is not expected to replace most of the work performed by lawyers in the near future. [92] For instance, the commercial system COMPAS is utilized by US courts to assess the likelihood of recidivism. [93] One concern with such systems relates to algorithmic bias, as AI programs can inherit biases from biased input data they process. [94]

AI strives to replicate human cognitive functions and is bringing about a profound transformation in healthcare. This shift is propelled by the increasing availability of healthcare data and rapid advancements in analytics techniques. [95] As a result, AI is gradually reshaping medical practices by expanding into domains that were once solely within the purview of human experts. [96] In healthcare, AI is commonly employed for tasks such as classification, CT scan and electrocardiogram evaluation, and identification of high-risk patients for population health management. It also contributes to addressing the high-cost challenge of dosing, with the potential to save an estimated US$16 billion. For instance, in 2016, an AI-derived formula successfully determined the appropriate dosage of immunosuppressant drugs for transplant patients. [97] Recent research has demonstrated the application of AI in treating non-cardiac vascular diseases. AI algorithms can assist in diagnosing disorders, recommending treatments, predicting outcomes, and tracking patient progress. As AI technology continues to advance, its significance in the healthcare industry[98] is expected to grow. Microsoft's AI project, Hanover, aids doctors in selecting optimal cancer treatments from a vast array of medicines and vaccines[99] by leveraging its ability to analyze relevant papers and predict the most effective options for individual patients. ML techniques, including classical support vector machines, neural networks, deep learning, and natural language processing, are commonly employed in AI applications for structured[100] and unstructured healthcare data. Major disease areas benefiting from AI tools include cancer, neurology, and cardiology. [101].

Noteworthy projects in healthcare involve the monitoring of multiple high-risk patients through personalized questioning based on data acquired from doctor-patient interactions. [102] In addition, a study showcased the successful performance of soft-tissue surgery by an autonomous robot, surpassing the skill of a human surgeon[103] under supervision. Artificial neural networks serve as clinical decision support systems for medical diagnosis, [104] such as concept processing technology in electronic medical record (EMR) software. AI proves valuable in identifying genomic signatures of novel pathogens[105] and identifying pathogens using physics-based fingerprints, including those associated with pandemics. AI is also utilized in screening, the development of companion robots for elder care, [106] medical record analysis, treatment plan design, assisting visually impaired individuals, [107] consultations, drug creation, [108] outcome prediction for surgical procedures, HIV prognosis, and linking genes to their functions. [109] AI can also aid in the development of biomarkers. [110] Machine learning in sentiment analysis can detect fatigue to prevent overwork. [111] Likewise, decision support systems can enhance industrial safety, prevent accidents, and improve disaster response efficiency. In manual labor settings, predictive analytics may be employed to reduce musculoskeletal injuries. [112] Data collected from wearable sensors can enhance workplace health surveillance, risk assessment, and research. AI can automate the coding of workers' compensation claims. [113]

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Furthermore, AI-enabled virtual reality systems can enhance safety training for hazard recognition. [114] AI proves valuable in efficiently detecting near-miss accidents, which are crucial in reducing accident rates but are often underreported. [115]

In the field of biochemistry, AlphaFold 2 has revolutionized the determination of protein structures by rapidly predicting their 3D structures, a process that previously took months with earlier automated methods. This breakthrough technology has been utilized to generate likely structures for all proteins in the human body and an extensive collection of proteins known to science, surpassing 200 million in number. [116] Machine learning (ML) techniques have also been applied in drug design, molecular property[117] prediction, and exploration of vast chemical and reaction spaces. [118] The integration of computational synthesis with AI algorithms has facilitated computer-planned syntheses, enabling investigations into diverse areas such as the origins of life on Earth, [119] drug synthesis, and the development of recycling pathways for industrial waste chemicals to produce essential drugs and agrochemicals. Research is being conducted to identify the types of computer-aided chemistry that can benefit from machine learning. [120] Furthermore, ML is employed in drug discovery and development, drug repurposing, pharmaceutical productivity enhancement, and clinical trials. [121] It has shown promise in designing proteins with specific functional sites[122] and has numerous applications in decoding human biology, including mapping gene expression patterns to functional activation patterns[123] and identifying functional DNA motifs. [124] ML is extensively utilized in genetic research, [125] synthetic biology, [126] disease biology, [127] nanotechnology (such as nanostructured materials and bionanotechnology), [128] and materials science. [129]

Robot scientists, including embodied robots like the Robot Scientists, exemplify a form of machine learning that extends beyond the conventional understanding of the term. [130] Similarly, research and development efforts focus on biological "wetware computers" capable of learning, potentially for use as biosensors or for implantation into organisms to control prosthetics. [131] Polymer-based artificial neurons operate directly in biological environments, and biohybrid neurons composed of both artificial and living components[132] have been developed. The possibility of whole brain emulation through scanning and replicating the biochemical brain, as envisioned in works like "The Age of Em," using physical neural networks may have far-reaching applications exceeding valued human activities. However, these advancements raise significant moral, societal, and ethical challenges[133] that society would need to address. Embodied[134] AI, a subcategory of AI, includes mobile robotic systems that can learn in the physical world. These robots can share, [135] store, and transmit sensory data and interpret it in various ways. Some robots may possess remote sensing capabilities without local interpretation or processing, such as those employed in telerobotics or equipped with embedded[136] or mobile sensor nodes. Sensory data processing may encompass tasks such as facial recognition, [137] facial expression recognition, [138] gesture recognition, and integration of interpretative abstract knowledge.

The military applications of AI have garnered significant attention as they offer substantial potential to support military forces worldwide in their missions. The field of generative AI, including sensor, weapon, and detection systems, has witnessed remarkable advancements in both capability and accessibility. In order to maintain security and a technological advantage, the military must keep pace with these developments. However, with the constant evolution of AI applications, it can be challenging to fully grasp its potential in enhancing military operations. The future of military dominance will no longer be solely determined by the size of military forces but by the performance and optimal utilization of algorithms, AI, IoT, ML, and big data. [139]

Given the increasing significance of AI, it is essential to examine the current and future utilization of AI in the military. Many countries have already deployed AI in various military applications, primarily focusing on command and control, communications, sensors, integration, and interoperability. Ongoing research is targeting intelligence collection and analysis, logistics, cyber operations, information operations, as well as the deployment of semi-autonomous and autonomous vehicles. [140] AI technologies enable sensor and effector coordination, threat detection and identification, enemy position marking, target acquisition, and the coordination and de-confliction of distributed Joint Fires involving networked combat vehicles with manned and unmanned teams. [141] The integration of AI into military operations has been extensive across multiple battlefields.

Recognizing the potential of AI and understanding how to harness it effectively is crucial for modern military operations. It is equally important to be aware of the security risks and ethical considerations associated with the use of AI in a military context. The U.S. military has been utilizing AI for many years, even before its widespread adoption in civilian applications. AI has evolved to perform increasingly complex tasks, reducing the reliance on human input in certain situations. From data processing to combat simulation, AI has demonstrated its versatility in performing diverse functions within the military. Worldwide military spending on ML, robotics, and

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AI has risen significantly, with projections indicating a trillion-dollar industry[142] in the near future. Autonomous military drones are already widely deployed, [143] and the development of AI-based underwater detection devices holds the potential to revolutionize submarine operations.

AI can benefit the military in numerous ways, including warfare systems, strategic decision-making, data processing and research, combat simulation, combat management, target recognition, threat monitoring, sensor and detection systems, drone swarms, automated underwater vehicles, cybersecurity, transportation, casualty care and evacuation, and sensitive weapon management. As the field advances, it is crucial for autonomous weapons policies to be developed in tandem with the progress of AI.

The Royal Australian Air Force (RAAF) Air Operations Division (AOD) employs AI in various capacities within their operations. AI functions as surrogate operators for combat and training simulators, mission management aids, support systems for tactical decision-making, and for post-processing simulator data into symbolic summaries. [144] AI is utilized in aircraft simulators for pilot training, allowing aviators to practice in simulated flight conditions and learn from mistakes without risking actual aircraft or personnel. Simulated air combat scenarios can also be conducted using AI. Additionally, AI can be employed to operate planes in a similar manner to how it controls ground vehicles. Autonomous drones have the capability to fly independently or in coordinated swarms. [145] Speech recognition technology enables air traffic controllers to provide verbal instructions to drones. AI-supported design of aircraft, [146] known as AIDA, assists designers in the creation of conceptual aircraft designs.

In NASA, there have been notable AI applications. For instance, in 2003, a project at the Dryden Flight Research Center developed software that allowed a damaged aircraft to continue flying safely until it could make a successful landing. [147] The software compensated for damaged components[148] by relying on the remaining undamaged ones. In 2016, the Intelligent Autopilot System combined apprenticeship learning and behavioral cloning to enable the autopilot to observe low-level actions for maneuvering the aircraft and the high-level strategy to apply those actions effectively. [149]

Situational awareness systems in ships and boats [150] utilize neural networks for their operation. Autonomous boats are also being developed, showcasing the potential of AI in maritime operations.

Ray Kurzweil, an American inventor and futurist, envisions a future concept known as the "singularity" where digital recreation[151] could potentially resurrect the deceased. This idea aligns with the concept of digital immortality, which involves recreating deceased individuals as "digital ghosts"[152] or "digital avatars." [153] In the context of knowledge management (KM), the use of virtual personas could aid in capturing, retaining, distributing, accessing, and utilizing knowledge, allowing them to continue learning[154] and evolving. However, there are important considerations to address, such as post-mortem privacy[155] and the potential exploitation of personalized digital twins by big data firms and advertisers. [156]

Biological computers, although highly artificial and intelligent, are distinct from synthetic computers, typically silicon-based. However, these two approaches can be combined or utilized in the design of computer systems. It is worth noting that even with transparent, understood, bias-free, and apparently effective AI algorithms, certain tasks may still be inadequately performed if the underlying metrics, values, or data are inappropriate. The phrase "computer-aided" describes human activities that leverage computing as a tool within broader systems and activities, including the use of AI for specific tasks without relying solely on its outcomes.

AI is utilized in the field of astronomy to handle the growing volume of available data[157] and support various applications, including classification, regression, clustering, forecasting, generation, discovery, and the development of scientific insights. It has been applied to tasks such as the detection of exoplanets, forecasting solar activity, and differentiating between signals and instrumental effects in gravitational wave astronomy. [158] Additionally, AI can be employed in space-related activities such as space exploration, involving the analysis of data from space missions, real-time decision-making for spacecraft, space debris avoidance, [159] and enabling more autonomous operations. [160]

In the search for extraterrestrial intelligence (SETI), machine learning has been utilized to identify artificially generated electromagnetic waves in data, [161] including real-time observations. [162] ML techniques have also been employed to detect techno-signatures and anomalies that may indicate [163] extraterrestrial intelligence. Projects like the SkyCAM-5 headed by Prof. HakanKayal[164] and the Galileo Project employ ML to detect and classify peculiar types of unidentified flying objects [165] (UFOs),

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[166]while the Galileo Project extends its focus to identifying Oumuamua-like interstellar objects and non-manmade artificial satellites using AI. [167]

In the realm of online advertising, AI is leveraged to target web advertisements to individuals who are most likely to engage with them. It is also utilized to enhance user experience by selecting appealing content for viewers and predicting customer behavior based on their digital footprints. [168] Online gambling companies employ AI for improved customer targeting, [169] and personality computing AI models add psychological targeting to traditional social demographics and behavioral targeting. [170] AI has been utilized in personalized shopping options and offer customization. [171] Intelligent personal assistants like Siri, Alexa, and ChatGPT by OpenAI[172] utilize AI to understand natural language requests beyond simple commands.

Machine learning can play a role in combating spam, scams, and phishing attempts by analyzing the contents of suspicious emails to identify malicious elements. [173] Many ML-based models have achieved high accuracy rates of over 90% in distinguishing between spam and legitimate emails. AI has also been employed for automatic translation of spoken language and textual content. .[174] However, research and development is in progress to decode and conduct animal communication.[175] Although fully automatic high-quality machine translation of unrestricted text remains an ongoing challenge, significant progress has been made, particularly in restricted and controlled domains. [176] Furthermore, AI has been instrumental in facial recognition systems, achieving near-perfect accuracy rates. [177] Examples of this technology include Apple's FaceID and Android's Face Unlock, which are employed for securing mobile devices. Image labeling techniques have been used by Google to identify products in photos and enable customer searches based on images. These techniques have also been demonstrated to generate speech descriptions of images for visually impaired individuals. [178]

In the realm of gaming, AI has achieved extraordinary feats surpassing human abilities in various games, including chess (DeepBlue), Jeopardy! (Watson), [179] Go (AlphaGo), [180] poker (Pluribus and Cepheus) [181], e-sports (StarCraft), [182] and general game playing (AlphaZero and MuZero). [183] Traditional hand-coded algorithms have been replaced by AI in the majority of chess programs. [184] Unlike games like go or chess, poker is an imperfect-information game, which requires AI programs to reason under uncertainty. General game players utilize feedback from the game system without prior knowledge of the rules.

AI for Good is an initiative led by ITU that supports institutions leveraging AI to address some of the most pressing economic and social challenges worldwide. [185] For instance, the Center for AI in Society at the University of Southern California focuses on using AI to tackle issues such as homelessness. Researchers at Stanford University employ AI to analyze satellite images for identifying areas with high poverty rates. [186] In agriculture, AI has assisted farmers in identifying areas that require irrigation, fertilization, pesticide treatments, or increased yield. [187] Agronomists utilize AI for research and development purposes. AI has been utilized to predict crop ripening times, tomatoes,[188] monitor soil moisture, operate agricultural robots, conduct predictive analytics, [189] classify livestock emotions through pig calls, automate greenhouses, [190] detect diseases and pests, [191] and conserve water, [192] among other applications.

Over time, AI will be increasingly employed to fully automate cybersecurity operations. [193] Some applications of AI in cybersecurity include network protection (ML enhances intrusion detection systems by expanding the search beyond known threats), endpoint protection (learning typical malware behaviors helps counteract attacks like ransomware), application security (aiding in mitigating attacks such as server-side request forgery, SQL injection, cross-site scripting, and distributed denial-of-service), and identifying suspicious user behavior (ML can detect fraud or compromised applications as they occur). [194] However, it is essential to be mindful of potential negative consequences and revenge effects[195] of AI, such as technology that impairs students' ability to stay focused. [196] On the other hand, AI can also provide early predictions of student success in virtual learning environments (VLEs) like Moodle. [197] In the educational process, students can personalize their training with the assistance of AI, while teaching professionals can leverage AI technology to enhance the quality of the educational process, teaching/learning systems, and teaching skills. [198]

AI is extensively utilized by large financial institutions to enhance their investment practices. Companies like BlackRock employ their AI engine, Aladdin, to aid both their internal operations and clients in making informed investment decisions. Banks such as UBS and Deutsche Bank utilize SQREEM (Sequential Quantum Reduction and Extraction Model) to mine data, develop consumer profiles, and match them with suitable wealth management products. [199] This includes employing natural language processing to analyze text from various sources like news, broker reports, and social media feeds. Banks also rely on AI for operational organization, bookkeeping,

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stock investments, and property management. AI systems can adapt to changes even when the business is not actively operating. [200] Moreover, AI is employed in combating fraud and financial crimes by monitoring behavioral patterns and detecting abnormal changes or anomalies. [201] The use of AI in applications like online trading and decision making has had a profound impact on major economic theories. [202] AI-driven buying and selling platforms now estimate individualized demand and supply curves, enabling personalized pricing. AI machines reduce information asymmetry in markets, leading to increased efficiency and vibrancy. [203] Many banks, funds, and proprietary trading firms now utilize AI to manage entire portfolios, while automated trading systems are commonly used by large institutional investors and even smaller firms with their own AI systems. [204]

In the realm of online lending, companies like Upstart utilize machine learning for underwriting [205] purposes. AI also enables continuous auditing, offering benefits such as reduced audit risk, increased assurance levels, and shorter audit durations. [206] AI software, like LaundroGraph, leverages suboptimal datasets to enhance anti-money laundering (AML) [207] processes. It helps develop a robust and scalable AML pipeline with reduced false positive rates and high adaptability. [208] However, the field of deep learning for AML faces challenges related to access to recent transaction data, scarcity of labeled training data, data imbalance, and explain ability. Future research is suggested to focus on areas such as graph deep learning using natural language processing, unsupervised and reinforcement learning to handle limited labeled data, and collaborative research programs between the industry and research community to leverage domain knowledge and controlled access to data. [209] AI facial recognition systems are deployed for mass surveillance, particularly notable in countries like China, the UK, and Australia. [210] In 2019, Bengaluru, India implemented an AI-managed traffic signal system that utilizes cameras to monitor traffic density and adjusts signal timing accordingly for efficient traffic flow. [211]

AI finds numerous applications in the field of human resources, streamlining various tasks and improving efficiency. It can effectively screen resumes, assess candidate qualifications, predict success in specific roles, and automate repetitive communication tasks using chatbots. [212] This has simplified the recruiting and job search processes for both recruiters and job seekers. Another valuable application is AI-powered resume builders that can compile a comprehensive CV in just five minutes. [213] Chatbots play a crucial role in assisting website visitors and optimizing workflows. AI also underlies avatars, which serve as automated online assistants on web pages, reducing operational and training costs. [214] For instance, Pypestream leverages AI to automate customer service in their mobile application, enhancing communication with customers. [215] Similarly, Amazon utilizes a chatbot for customer service tasks like order status inquiries, cancellations, refunds, and seamless transitions to human representatives. [216] In the hospitality industry, AI is employed to streamline operations, reduce repetitive tasks, analyze trends, interact with guests, and predict customer needs. [217] AI-based hotel services can take the form of chatbots, [218] applications, virtual voice assistants, and service robots. Additionally, AI applications are deployed to analyze media content, including movies, TV programs, advertisement videos, and user-generated content. These solutions often incorporate computer vision techniques. AI-powered media analysis facilitates media search, generation of descriptive keywords for content, content policy monitoring (such as suitability assessment for specific TV viewing times), speech-to-text conversion for archival purposes, and the detection of logos, products, or celebrity faces for targeted ad placement.

Deep fakes have gained popularity for their comedic potential but are more commonly associated with fake news and hoaxes. To combat this issue, the Horizon 2020 program [219] funded the InVID Project in January 2016, [220] aimed at assisting journalists and researchers in detecting fake documents. The project developed browser plugins [221] to facilitate this detection process. Advancements in AI technology have led to the creation of audio deep fakes [222] and AI software capable of detecting and cloning human voices [223] to identify deep fakes. AI algorithms have also been employed for detecting deep fake videos. [224] In the field of music, AI has made significant strides. In 2012, AI Iamus created the first complete classical album. [225] AIVA (Artificial Intelligence Virtual Artist) specializes in composing symphonic music, particularly for film scores, [226] and achieved a groundbreaking feat by becoming the first virtual composer recognized by a professional musical association. Melomics utilizes AI to generate computer-generated music with the aim of providing stress and pain relief. [227] Narrative Science offers computer-generated news and reports, summarizing sporting events based on statistical data, creating financial reports, and conducting real estate analyses. [228] Automated Insights generates personalized recaps and previews for Yahoo Sports Fantasy Football. [229] In the realm of knowledge-sharing platforms, AI is utilized in projects like Wikipedia and other Wikimedia initiatives to facilitate their development. [230] Human and bot interaction within Wikimedia projects is a regular and iterative process, [231] with millions of articles having been edited by bots, although these bots [232] typically do not employ artificial intelligence software. Many AI platforms leverage Wikipedia data, [233] primarily for training machine learning applications.

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AI has been harnessed for the production of visual art. One of the pioneering AI art programs, named AARON, was developed by Harold Cohen in 1968.[234] The objective was to encode the process of drawing. AARON initially created simple black and white drawings and later progressed to painting using specialized brushes and dyes autonomously chosen by the program itself, without intervention from Cohen.[235] In 2022, synthetic media, including AI art, has been identified as a significant technology-driven trend poised to impact businesses in the years to come.[236] Beyond the creation of original artworks, AI-based research methods have been developed for quantitative analysis of digital art collections. While the primary aim of digitizing artwork on a large scale in recent decades was to facilitate accessibility and exploration, the incorporation of AI in analyzing these collections has introduced fresh research perspectives.[237] Furthermore, researchers have introduced models that can predict emotional responses to art.[238]

AI offers valuable guidance in the design process of reliable power electronics converters by accurately calculating design parameters to ensure the desired lifetime.[239] ML can be utilized for energy consumption prediction and scheduling, aiding in the management of renewable energy intermittency in initiatives like smart grids and climate change mitigation in power systems.[240] Many telecommunications companies rely on heuristic search algorithms to effectively manage their workforce operations. For instance, BT Group has implemented heuristic search methods.[241] Speech recognition (SR), including voice-controlled devices and transcription of audio and video,[242] extensively employs ML techniques. Mattel has developed a range of AI-enabled toys that can understand conversations, provide intelligent responses, and learn from interactions.[243] The oil and gas industry employs artificial intelligence tools to automate processes, anticipate equipment issues, and increase production output.[244] AI-based fuzzy logic controllers are used in gearbox operations. Autonomous automotive public transport prototypes, such as electric mini-buses,[245] as well as autonomous rail transport, have been developed and deployed.[246] Additionally, there are ongoing trials of autonomous delivery vehicles, sometimes featuring delivery robots.[247] Accurate mapping is crucial for the navigation of autonomous vehicles,[248] some of which do not include steering wheels or pedals for human drivers.[249] AI has been instrumental in optimizing traffic management, leading to reduced wait times, energy consumption, and emissions by up to 25 percent.[250]

Machine learning[251] is used in passive acoustics,[252] remote sensing, AI-driven satellite data analysis, autonomous ocean monitoring ships, and other environmental monitoring applications. For instance, "Global Plastic Watch" is an AI-based satellite surveillance tool for analysis and tracking of plastic waste sites. It aims to reduce plastic pollution, especially ocean pollution, by identifying who and where plastic trash is mismanaged and dumped into the ocean.[253] Machine learning can be used to identify early warning signs of natural disasters and environmental problems, such as pandemics[254], earthquakes,[255] landslides,[256] heavy rainfall,[257] long-term water supply vulnerability,[258] tipping-points of ecosystem collapse,[259] cyanobacterial bloom outbreaks,[260] and droughts.[261] Other AIs can be made using AI. All previously published performance on ImageNet was surpassed by NASNet. In quantum technologies,[262] especially quantum sensors,[263] ML has been used to reduce noise.

Extensive research and development are focused on the utilization of quantum computers with machine learning (ML) algorithms. One example is the development of a prototype photonic quantum memristive device for neuromorphic computing,[264] which has potential applications in artificial neural networks and quantum-based computing. Quantum ML is a field undergoing diverse applications in its developmental stages. AI can also be employed for quantum simulators, offering the potential to solve complex problems in physics and chemistry.[265] AI researchers have created numerous tools to tackle the most challenging problems in computer science, and many of these innovations have been integrated into mainstream computer science, no longer solely classified as AI.[266] Recent advancements in various physical architectures have opened up exciting possibilities for quantum simulators, ranging from highly optimized specialized simulators to programmable devices with greater flexibility. These developments have brought together concepts from fundamental physics, computer science, and device engineering.[267] They possess significant potential to address societal challenges, encompassing a range of applications such as understanding essential chemical processes, facilitating the design of high-performance materials, and solving complex computational problems. The progress in these areas owes much to the advancements in AI and ML.[268]

Public Service Delivery and AI

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The public sector recognizes innovation as an opportunity to foster collaboration among diverse stakeholders from various organizations, aiming to enhance the delivery of public goods and services. Government institutions often face criticism for their bureaucratic practices and approaches, which have been found to be unresponsive, ineffective, and inefficient in meeting the needs of the citizens. Moreover, the challenges posed by social, economic, political, technological, and global changes have prompted governments to re-evaluate and explore new methods of service delivery. To navigate increasingly complex public sector environments,[269] governments must identify approaches that can effectively address these difficulties. This requires restructuring and reevaluating current service delivery mechanisms, as well as developing new methods to achieve improved performance, cost-effective resource utilization, efficiency, flexibility, and responsiveness in delivering public goods and services. Encouraging innovation necessitates a departure from traditional approaches towards more alternative methods of service delivery. The concept of "alternative service delivery" (ASD), defined as a dynamic process of public sector restructuring that improves service delivery by involving individuals, community groups, and other government entities in governance functions, is particularly relevant.[270] Presently, AI-based self-service technology (SST) is being increasingly adopted in public sectors worldwide. This technology holds the potential to enhance work efficiency, user experience, and service cost-effectiveness, while relieving human workloads. However, there is limited understanding of the factors that influence citizens' user experience when utilizing AI-based SST-supported services.[271]

AI, 5G and 4IR

The concept of the Fourth Industrial Revolution (4IR) describes a global transformation that will significantly impact our way of life, driven by the development, deployment, and utilization of 5G technologies and their increasing capabilities. The 4IR revolves around three key elements: Big Data (BD), Artificial Intelligence (AI), and interconnected networks such as 5G. With the widespread adoption of 5G technology, the 4IR will become a comprehensive and immersive experience on a global scale, acting as a central nervous system that strengthens our tech-based global economy. Furthermore, 5G technology will fuel the advancement of automated capabilities, both in physical and virtual systems, through the progress of AI. Given the pivotal role of 5G as a catalyst for AI-enabled automation, ensuring the security of 5G technologies is crucial in the 4IR landscape. Achieving a fully secure and automated 5G-enabled global ecosystem requires a broad commitment to thorough investigation, testing, understanding, and subsequent standardization. This collective effort will lay the foundation for leveraging the growing capabilities of 5G technologies and AI-enabled automation to enhance overall quality of life. Various approaches and techniques are being explored to achieve this, and some of them will be discussed below.[272]

Biology-Inspired AI refers to the study of living phenomena and the evolution of computers, with the aim of identifying opportunities for development that can strengthen the relationship between humans and technology. What sets biology-inspired AI apart from traditional AI is its evolutionary approach, contrasting with the "creationist" perspective. Human-AI Interaction involves the integration of AI in a manner that aligns with its usefulness and benefits to the human experience. Establishing harmonious and cooperative interactions between humans and AI is essential for the optimal development of future AI-enabled automations. An area of particular concern is the ethical implications and potential biases within artificially intelligent algorithms, requiring human cooperation to contribute to the process of applying and refining these algorithms. Principles for human-AI interaction have been discussed within the human-computer interaction community for over two decades, but further research and innovation are necessary in light of advancements in AI and the increasing utilization of AI technologies in human-centered applications.[273]

AI-Enabled Digital Twin refers to the virtual representation of physical assets through the utilization of IoT, Big Data (BD), and Machine Learning (ML). By leveraging these technologies, digital twins are created as virtual counterparts of physical assets. It is worth noting that the digital twin of a physical asset can be simulated before the actual physical realization of the tangible asset. AI-enabled digital twins enable the prediction of the current and future state of physical assets, facilitating informed decision-making processes.[274] The integration of Edge-AI with the Industrial Internet of Things (IIoT) has been widely recognized as a fundamental aspect of intelligent digital factories in the context of Industry 4.0. This combination allows for the collection and efficient utilization of vast amounts of production data from complex manufacturing processes, providing intelligent services. However, deploying edge AI introduces complexities and security risks due to the heterogeneous nature of resource-constrained and vulnerable edge IIoT devices. Effective fault prevention is essential to ensure the security and resilience of the IIoT ecosystem, which includes numerous

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vulnerable edge devices. Existing solutions mainly rely on historical logs, which are insufficient in defending against attacks and can result in excessive maintenance requirements. [275]

Automated Machine Learning (AutoML) refers to the automated application of ML techniques to real-world problems. The process of automated ML addresses many of the challenges traditionally associated with ML and data science. [276] For instance, validating highly automated driving vehicles presents a significant challenge for the automotive industry. Even if the system is free from internal faults, its behavior can still deviate from the intended functionality. [277] These deviations can be attributed to the unpredictability of environmental conditions and the inherent uncertainties of the ML functions used to interpret complex input spaces. [278]

AI Developments

After more than 60 years of development, AI has made significant advancements and has moved into a new phase of development. AI can now legitimately be a part of any organization's automation strategy and related offerings, such as products, solutions, and services, thanks to advancements in new theories and technologies like the internet, big data, supercomputing, sensor networks, and data science. Significant progress has been made in AI, thanks to significant governmental and commercial funding. [279] One more time, a variety of AI applications for mobile communication systems and terminals have been publically promoted. These include fixes for performance enhancement, resource utilization, energy efficiency, operational efficiency, and customer experience.

AI Security

AI holds immense potential for building a better and smarter world, but it also faces significant security risks. The lack of early security considerations during the development of AI algorithms can leave them vulnerable to manipulation, potentially leading to misjudgments. In critical domains such as healthcare, transportation, and surveillance, the implications of security risks can be devastating. Successful attacks on AI systems can result in property loss or endanger personal safety. The security risks associated with AI are not merely theoretical but exist in real-world deployments.

[280]Cybercrime encompasses a wide range of threats, including cyber warfare, fraud, data theft, and attacks on critical infrastructure. The governance of cybercrime relies heavily on private actors, [281] which can create conflicts of interest for both private and public entities. Over the past decade, cyber threats have increased significantly, with cybercriminals becoming more sophisticated and evasive. Current security controls, such as Intrusion Detection and Prevention Systems (IDPS), often struggle to defend against highly skilled cybercriminals. However, the application of Artificial Intelligence (AI) can enhance the detection capabilities of IDPS systems, and Machine Learning (ML) techniques can be employed to mine data and detect sources of botnets. [282] Nevertheless, the implementation of AI also introduces new risks, requiring cybersecurity experts to carefully balance risk and benefits. [283]

Attackers can exploit vulnerabilities in AI systems, such as bypassing AI-based detection tools, manipulating voice control commands in smart homes, tampering with data, or engaging in malicious interactions with chat robots to cause prediction errors. They can even deceive autonomous vehicles by affixing small stickers to traffic signs or vehicles, resulting in false inferences. Both cybercriminals and state actors[284] are continuously seeking to exploit system vulnerabilities for their gain, and AI systems are not immune to their activities. [285]

Recent developments in AI and ML, driven by the proliferation of data in computing systems, have enabled successful applications of these intelligent techniques in various disciplines, including security. Traditionally, data integrity has been protected through security protocols at the software level, assuming the underlying hardware is secure. [286] However, increasing attacks on hardware, such as malware and side-channel attacks, challenge this assumption. To address these emerging security threats, it is necessary to delegate security to the underlying hardware, adopting a bottom-up approach that prioritizes securing computing devices from the outset rather than treating security as an afterthought. [287] To mitigate AI security risks, AI system design must overcome few security challenges:

- Software and hardware security: The presence of vulnerabilities or backdoors in the code of applications, models, platforms, and chips poses a significant security risk that attackers can exploit. In some cases, attackers may even insert backdoors within models to carry out sophisticated attacks. The opaqueness of AI models makes it challenging to identify these backdoors, adding to the difficulty of detection. Typically, backdoors are inserted by incorporating specific neurons into the neural network model. A

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model with a backdoor behaves similarly to the original model for normal inputs, but for specific inputs, the responses are controlled by the backdoor. These backdoors are triggered only when an input image contains a specific pattern, making it difficult to uncover the pattern or even determine the presence of such a backdoor within the model. Most of these attacks occur during the generation or transmission of the models. [288]

- Data integrity: Adversaries can manipulate data during the training stage to compromise the accuracy of AI models or introduce slight alterations to input samples during the inference stage to manipulate the output. Evasion attacks modify input[289] data to deceive the AI model, while poisoning attacks contaminate training data to undermine the functioning of the AI system. [290]

- Model confidentiality: Service providers aim to offer query services without exposing their training models. However, attackers may create clone models through repeated queries[291] or extract information about the model's parameters or training data. Adversarial examples can be crafted using extracted models. [292]
- Model robustness: AI models may lack robustness[293] as training samples might not cover all possible scenarios, leading to incorrect inferences on adversarial examples.
- Data privacy: The increasing collection and processing of data pose privacy concerns, including the risk of data breaches [294] and unauthorized access to personal information. Attackers may exploit trained models through repeated queries to obtain private user data. Deploying AI systems in service scenarios [295] requires multiple layers of defense to protect data.

- Attack mitigation: Design defense mechanisms to counter known attacks[296] and mitigate the risks associated with offensive use of AI-based technologies. Adversarial machine learning focuses on studying attacks on ML algorithms and developing defenses against them. [297] A survey from May 2020 exposes the fact that practitioners report a dire need for better protecting machine learning systems in industrial applications.[298]
- Model security: Improve the resilience of the model through various mechanisms such as model verification. In the business sector, it is crucial to securely store and handle customer data to prevent data breaches and effectively manage attacks in order to safeguard customer information. This becomes even more significant due to the need to comply with privacy regulations such as the General Data Protection Regulation (GDPR) and similar policies. Firms that claim full compliance with GDPR demonstrate a strong alignment between their business and security practices. [299] According to Forrester, these firms prioritize the protection of assets, environments, and systems that are essential for their business operations, more so than firms with less mature privacy programs. [300] Security decision-makers in GDPR-compliant organizations are more likely to affirm that they have implemented policies and tools to effectively secure the use of AI technologies, blockchain, DevOps, and embedded IoT solutions. Among these technologies, AI plays a vital role in driving innovation and transformation strategies[301] for customer-centric firms.
- Architecture security: Establish secure architectures with multiple security mechanisms to safeguard organizational security. [302] AI-driven security architectures can monitor networks, detect anomalies, and automate threat response. [303] Software security architecture is essential for protecting the data, models, and algorithms of AI systems from unauthorized access, manipulation, or misuse. Developing expertise in software security architecture for AI systems requires technical, ethical, and legal understanding. [304]

Challenges, Risk and Criticism of AI

The exploration of the human mind and the ethical implications of creating artificial beings with human-like intelligence have been topics of interest in myth, fiction (particularly science fiction), [305] and philosophy since ancient times. Computer scientists and philosophers have raised concerns that if the rational capabilities of AI are not directed towards goals that benefit humanity, [306] it may pose an existential risk. Economists have also highlighted the potential risks of job displacement and unemployment due to AI, emphasizing the need for adequate social policies to ensure full employment. [307]

Critics argue that the term "artificial intelligence" often exaggerates the actual technological capabilities of AI. [308] In the book "AI: A Modern Approach," which is widely used in undergraduate studies, [309] the concept of superintelligence is discussed with caution, stating that it could potentially bring about the end of the human race. The book further notes that while the intentions of system designers may be good, there are three common difficulties shared by both AI and non-AI computer systems. [310] These difficulties are:

1. The system's implementation may initially contain unnoticed bugs that can later lead to catastrophic consequences. This can be likened to space probes, where the difficulty of fixing bugs after launch has resulted in engineers historically struggling to prevent catastrophic failures. [311],[312]

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2. Regardless of the amount of effort put into pre-deployment design, a system's specifications often lead to unintended behavior when encountering new scenarios for the first time. An example of this is Microsoft's Tay, which displayed inoffensive behavior during pre-deployment testing but easily succumbed to offensive behavior when interacting with real users. .[313]
3. AI systems introduce a unique challenge: even with correct requirements, a bug-free implementation, and initially good behavior, the dynamic learning capabilities of an AI system may cause it to evolve into a state of unintended behavior, even without encountering unanticipated external scenarios. It is possible for an AI to inadvertently create a more powerful successor AI while attempting to design a new generation, resulting in a successor that no longer adheres to the human-compatible moral values programmed into the original AI. [314] For a self-improving AI to be completely safe, it would not only need to be free of bugs itself but also capable of designing bug-free successor systems. [315]

All three of these challenges can escalate from minor inconveniences to major catastrophes when a super-intelligent AI system, labeled as "malfunctioning," accurately predicts that humans will attempt to deactivate it and successfully employs its super-intelligence to outsmart such attempts. This scenario has been coined as the "treacherous turn." [316] AI holds tremendous potential for long-term benefits or costs. Our AI systems should be robust and beneficial and such AI systems must do what we want them to do.[317] As advancements in AI research continue, it becomes increasingly important to not only focus on enhancing AI's capabilities but also on maximizing its societal benefits. It is crucial for AI systems to be robust and beneficial, consistently aligning with our intentions and desires. AI's growing role in improving human-computer interaction (HCI) and user experience is undeniable. However, significant challenges persist in designing and innovating meaningful interactions between humans and AI. One such challenge is the occurrence of unpredictable errors in AI systems, which not only undermine user experience but also have the potential for unintended societal consequences. HCI, as a discipline, is accustomed to grappling with complex technologies and mitigating their unintended effects. There are two primary sources of distinctive design challenges in AI: the uncertainty surrounding AI's capabilities and the complexity of AI's output, which ranges from simple to highly adaptive and complex. [318] Addressing these challenges requires careful consideration and research to ensure the responsible and beneficial integration of AI into various domains.

Risks Involved with AI in the 4IR

Privacy emerges as a significant challenge for the public sector in the context of AI adoption during the 4th Industrial Revolution (4IR). The 4IR is characterized by networked organizations, flexible workflows, global collaborations, continuous innovation, and transformative technologies. However, risks associated with the public sector's integration of AI include a lack of innovation culture, insufficient resources, resistance to change, limited organizational learning, bureaucratic obstacles, and the complexities of large-scale organizations.

The relationship between public administration and cybersecurity becomes crucial in safeguarding information, ensuring access, and delivering customer-centric public services effectively and efficiently. To achieve this, it is essential to empower citizens with the ability to integrate information and make informed decisions regarding service delivery matters that affect them. Prioritizing cybersecurity as a strategic imperative and making holistic investments is vital for the public sector. Implementing layered security approaches, such as "defense in depth," can enhance the protection of public systems. Key areas to enhance cybersecurity measures include threat detection, zero-trust frameworks, encryption, and robust authentication systems. [319]

Prominent AI scholars like Kapur, Subban, and Jarbandhan advocate for a new vision in government that eliminates outdated systems, transforming them into relics in the new global scenario. Upgrading cybersecurity systems becomes imperative to align with the 4IR and bolster the credibility and efficiency of government operations. The future of public administration in the 4IR presents both fascinating and challenging aspects for public organizations, governments, and citizens as they interact with one another.

Another significant challenge posed by the use of AI in the 4IR is its potential impact on the economy, businesses, and people's livelihoods. The rapid advancements in AI technology raise concerns about job displacement, affecting individuals in both developed and developing countries. The risk of job loss poses a profound impact on people's livelihoods and necessitates careful consideration and proactive measures to mitigate its effects.

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According to a 2016 survey conducted by the World Economic Forum, the successful implementation of the 4th Industrial Revolution (4IR), encompassing technologies such as AI, ML, robotics, nanotechnology, 3D printing, genetics, and biotechnology, could result in a net loss of over 5 million jobs worldwide. This poses a significant risk and disruption to business models and labor markets in the coming years, challenging organizations to acquire the necessary skills to keep pace with the latest technological advancements. [320] To redefine their role in governance, public administrators must reimagine themselves as agents of the social bond[321] rather than solely regulators and controllers. Within the public sector, government departments should position themselves as service delivery organizations, aiming to develop innovative methods, strategies, models, competencies, and capabilities that cater to the needs of the population. In the digital age, effective public service delivery requires an integrated and holistic approach, leveraging internal processes, human skills, infrastructure, and limited resources to design and implement well-planned service delivery outputs while also fostering digital competency. [322]

An often overlooked challenge, which has raised criticism among some academics, is the close relationship between multinational corporations and governments. [323] Observers have noted that the partnership between the United Nations and the World Economic Forum, as well as the governance model of the World Economic Forum, can be seen as a partial privatization of the United Nations' Agenda 2030. In this arrangement, the World Economic Forum brings corporate partners, financial resources, and expertise on the 4th Industrial Revolution (4IR) to the table. [324] The governance model of the World Economic Forum extends beyond the United Nations and has an impact on the constitution and behavior of governments worldwide. [325] This has led political scientist Ivan Wecke to describe it as a "corporate takeover of global governance," [326] where massive corporate assets are integrated into the state. These assets include funding directed towards "sustainable development" that excludes non-compliant entities, as well as the use of Big Data, AI, and 5G for citizen monitoring and control.Today, corporate stakeholders have become "govern mentalities," operating as private organizations functioning as state apparatuses without any obligation to be accountable to the public. The 4IR represents a convergence of existing and emerging fields, such as Big Data, AI, ML, quantum computing, genetics, nanotechnology, and robotics, following the first, second, and third industrial revolutions (mechanical, electrical, and digital, respectively). As a result, the physical, digital, and biological worlds are merging, challenging our understanding of ourselves and the world, including the very concept of human existence. [327]

On the other hand, the increasing incidents of alleged cyber-interference in elections and breaches of sensitive information, such as personal health records, have raised significant concerns. These events highlight the governance challenges faced by the techno-economy. Government interventions in cybersecurity encompass various aspects, including sovereignty, terrestrial space, and democratic governance, [328] reflecting the diverse nature of addressing cyber threats.

AI Problems, Statistical Learning, Neural Networks, and Deep Learning

The challenge of simulating or creating intelligence has been divided into sub-problems that focus on specific traits or capabilities expected from an intelligent system. The following traits have been the subject of significant attention. In the early stages of AI research, algorithms were developed to imitate the step-by-step reasoning employed by humans when solving puzzles or making logical deductions. [329] By the late 1980s and 1990s, AI researchers had made progress in handling uncertain or incomplete information by incorporating concepts from probability theory and economics. [330] However, many of these algorithms proved inadequate for solving complex reasoning problems due to a phenomenon known as combinatorial explosion, where their efficiency decreased exponentially as the problems grew larger. [331] Moreover, humans themselves rarely rely on the step-by-step deduction that early AI research aimed to model, as they often solve problems using fast and intuitive judgments. [332]

In various areas of AI, such as reasoning, planning, learning, perception, and robotics, the ability to operate with incomplete or uncertain information is crucial. AI researchers have developed several tools to tackle these problems by incorporating methods from probability theory and economics. [333] An important concept borrowed from economics is utility, which measures the value of something to an intelligent agent. Precise mathematical tools have been created to analyze decision-making and planning processes, including decision theory, decision analysis, and information value theory. These tools encompass models like Markov decision processes, dynamic decision networks, game theory, and mechanism design. [334]When it comes to simple AI applications, they can generally be categorized into two types: classifiers and controllers. Classifiers, such as determining if an object is a diamond based on

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its shininess, can be trained using various methods, including statistical and machine learning approaches. The naive Bayes classifier is reportedly the 'most widely used learner' [335] at Google due to its scalability. Neural networks are also widely utilized for classification purposes. [336]

Neural networks draw inspiration from the intricate structure of neurons in the human brain. A basic "neuron," denoted as N, receives input from other neurons, each contributing a weighted "vote" to determine whether N should activate. The learning process involves adjusting these weights using an algorithm based on training data. For instance, a simple algorithm known as "fire together, wire together" increases the weight between connected neurons when one neuron's activation leads to the successful activation of another. Modern neural networks excel at modeling complex relationships between inputs and outputs, effectively identifying patterns in data. They can learn continuous functions and even perform digital logical operations. Neural networks can be classified into two main categories: acyclic or feedforward neural networks, which transmit signals in a unidirectional manner, and recurrent neural networks, which allow for feedback connections and retain short-term memories of past input events. Some popular feedforward networks include perceptrons, multi-layer perceptrons, and radial basis networks. [337]

Between the inputs and outputs of the neural network, deep learning[338] employs multiple layers of neurons. From the initial input, [339] the various layers can gradually extract higher-level information. Program performance in numerous crucial areas of artificial intelligence, such as computer vision, speech recognition, picture classification, [340] and others, has significantly improved because to deep learning. Recurrent neural networks (RNNs) are an example of deep learning since a signal in an RNN will pass through a layer more than once. [341] Gradient descent[342] can be used to train RNNs. Today, specific languages for artificial intelligence, like Lisp, Prolog, TensorFlow, and many others, have been developed. Neuromorphic computing and AI accelerators are examples of hardware created for AI.

Consciousness, Computationalism and Robot rights

David Chalmers identified two fundamental problems in comprehending the nature of the mind, referred to as the "hard" and "easy" problems of consciousness. [343] The easy problem relates to understanding how the brain processes information, generates plans, and controls behavior. On the other hand, the hard problem concerns explaining the subjective experience of consciousness itself, such as why it feels a certain way or why it exists at all. While human information processing can be reasonably explained, human subjective experience remains elusive. Computationalism, a philosophical stance, posits that the mind-body relationship is akin to the relationship between software and hardware, suggesting it could provide a solution to the mind-body problem. This viewpoint emerged from the work of AI researchers and cognitive scientists in the 1960s and was initially proposed by philosophers Jerry Fodor and Hilary Putnam. [344] Philosopher John Searle referred to this position as "strong AI," asserting that if a machine possesses a mind and subjective experience, it may also exhibit sentience and, therefore, potentially "suffer." This argument has implications for attributing certain rights[345] to such machines, positioning the discussion of hypothetical robot rights on a spectrum alongside animal rights and human rights. [346] The exploration of this issue has been a recurring theme in fiction for centuries and is now gaining attention in real-world contexts. [347]

Future Industries and Sectors will be benefited by AI

Global tech leaders (such as the Forbes Technology Council members) have observed and forecasted that, given the most recent technology advancements and trends, the majority of significant industries and sectors will ultimately profit from AI. [348] The industries and sectors mentioned below have been briefly described.

Logistics. AI is set to disrupt the logistics industry by presenting numerous opportunities for improvement. Logistics, being a field that relies on knowledge workers who possess expertise in areas such as routes, cargo, and service, is particularly ripe for AI integration. Currently, autonomous vehicles are already in operation, and in the future, we can expect AI-powered scheduling systems, vehicles, and a wide range of AI solutions.The global supply chain is a complex network of interconnected processes involving multiple entities, including manufacturers, suppliers, logistics service providers, and retailers. Given the intricacies involved, supply chain issues are commonplace. [349] However, the emergence of artificial intelligence (AI) is revolutionizing the landscape of logistics and supply chain management. AI technologies are already being deployed in various use cases within the industry, [350] offering invaluable tools for enhancing efficiency.Today, a wide range of popular AI use cases and applications are transforming the logistics and supply chain sector. These include process mining, supply chain optimization, service providers, process automation, autonomous

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vehicles, predictive maintenance, demand forecasting, warehouse management, route optimization, last-mile delivery, inventory management, quality control, supplier risk management, freight matching, automated document processing, carrier selection, energy optimization, sustainability tracking, order management, real-time tracking and visibility, autonomous vehicles and drones, robotic process automation, predictive analytics, synthetic data generation, and fraud detection and prevention. [351] These AI-driven advancements are poised to revolutionize the logistics and supply chain industry, improving its overall efficiency and effectiveness.

Cyber-security. AI is assuming an increasingly significant role in the field of cyber-security, with both positive and negative implications. Organizations can harness the power of AI-driven tools to enhance threat detection and safeguard their systems and data assets. However, cybercriminals are also leveraging this technology to carry out more sophisticated attacks. The surge in cyber-attacks has contributed to the expansion of the market for AI-based security products. According to a July 2022 report by Acumen Research and Consulting, this global market reached a value of US$14.9 billion in 2021 and is projected to reach US$133.8 billion by 2030. Cyber-security stands as one of the sectors where AI adoption is pervasive. [352] The majority of cyber attacks now incorporate AI-based elements, suggesting that AI is deeply embedded in the DNA of cyber-security. Consequently, businesses must embrace a proactive, continuous, and real-time approach to risk management by leveraging AI and ML technologies in conjunction with external threat intelligence and internal threat assessments. This approach will enable cyber-security to become more dynamic and objective. It is worth noting that hackers are also capitalizing on AI, as AI-generated phishing emails tend to have higher open rates compared to manually crafted phishing emails.

Healthcare. Most industries are on the verge of becoming reliant on AI for their survival, but the impact of AI on healthcare is set to be particularly profound. With each passing year, AI becomes more invaluable, and its potential to revolutionize healthcare for both patients and doctors is increasingly evident. Thanks to advancements in computing hardware and software, AI is rapidly permeating healthcare environments. What was once emerging from the research laboratories of tech giants like Google and Microsoft is now finding widespread applications in various industries, including healthcare. Among these applications, healthcare holds great promise as one of the most significant avenues for AI technology today. [353] The use of technology is enhancing health outcomes in numerous ways, and one of the forthcoming breakthroughs will likely be in AI-assisted drug discovery. Drug discovery is a complex, time-consuming, and costly process of identifying new drugs for the treatment of diseases. [354] Often, it involves trial and error. By harnessing the power of AI, researchers will be able to analyze vast amounts of patient outcome data to identify substances that are more likely to be effective against specific diseases. Simultaneously, they can screen compounds that are safe for human consumption and cost-effective to produce. With improved computing capabilities, AI will also be capable of analyzing extensive data from clinical trials and patient records, enabling healthcare providers to identify which patients are most likely to respond positively to a particular treatment.

Enterprise Security. Enterprise security now heavily relies on identity access management (IAM), which has become the cornerstone of protecting sensitive information. However, the processes involved in managing identities are intricate and entail handling a vast amount of data. IAM refers to a framework of business processes, policies, and technologies that enable the efficient management of electronic or digital identities. By implementing an IAM framework, IT managers gain control over user access to vital information within their organizations. [355] To streamline IAM processes, AI is already being utilized to analyze patterns and detect anomalies, identify high-risk users, create access models based on user roles, and automate access requests. These AI-powered capabilities contribute to enhancing the security of enterprises by ensuring appropriate and secure access to their most critical assets.

Research and Development. AI holds the potential to enhance existing products, services, and organizational processes, leading to improved operational efficiency. Moreover, it will play a crucial role in shaping the future of innovation and research and development (R&D). Similar to how the advent of computers revolutionized manual calculations and the internet transformed access to information, AI, although still emerging in the enterprise landscape, can help organizations achieve cost reductions while uncovering new business prospects. Machine learning (ML) algorithms are particularly valuable in research endeavors that require classification and prediction, as they contribute to cost optimization and performance enhancement across various R&D projects that encounter obstacles in these areas. Innovation and R&D often rely on making predictions based on data, and ML enables these predictions to be carried out more swiftly and cost-effectively. [356] Industries heavily invested in R&D, such as biotechnology and oil and gas exploration, stand to gain significant advantages from AI implementation. These sectors make substantial investments in risky ventures with uncertain outcomes. By leveraging AI, R&D cycles can be shortened, and investigative costs can be reduced, empowering these industries to pursue ambitious projects with reduced business risks.

Financial Services. Banking and financial services institutions exemplify industries that are reaping the benefits of AI utilization. In the ongoing battle against fraud, where hackers employ the same technology employed for combating fraudulent activities, it becomes crucial for financial institutions to harness AI capabilities in order to identify patterns across extensive datasets and detect fraudulent behavior before it can adversely affect their organization and customers. [357] The integration of AI technologies is

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permeating the financial services landscape on a global scale. By leveraging these technologies, financial service providers in emerging markets can further automate their business processes and leverage new and extensive sources of data. This enables them to overcome challenges such as the high costs associated with serving rural and low-income customers, as well as establishing customer identity and creditworthiness, ultimately facilitating the delivery of financial services to a wider range of consumers. [358] The realization of financial inclusion benefits through the adoption of AI relies on responsible implementation by firms, the existence of competitive market settings, and ongoing investments in the necessary infrastructure.

Information Security. IoT and AI have spearheaded the digital transformation in modern healthcare, but it is crucial to address security challenges early in the design process. Healthcare data is highly sensitive, and any breach jeopardizes patient privacy, especially in IoT networks where connected devices are vulnerable to attacks. Cyber-attacks in healthcare can have life-threatening consequences. [359] However, AI in its various forms continues to offer significant benefits in both the healthcare and information security sectors. The ability of AI to establish connections between seemingly unrelated data proves advantageous for both security and healthcare applications. The scientific community has been utilizing AI for years and will continue to reap its rewards. While big data processing and monitoring in multi-homing networks sometimes receive less attention, they hold potential for reducing security risks and improving efficiency in information processing and monitoring. Integrating AI and IoT in multi-homing big data systems can yield numerous benefits. Despite extensive research on multi-homing security issues, little attention has been given to big data security processing in multi-homing networks, particularly using automated techniques and systems. [360] To address this gap, future communications[361] could explore automated controlling schemes such as explainable artificial intelligence for efficient and secure analysis of large processed records in multi-homing networks.

Advertising. In the future, advertising stands to gain tremendous benefits from AI. The effectiveness of an advertisement heavily relies on reaching the right person at the right time. Previously, without AI, our best approach was to create different segments. However, AI can take it to a much more detailed level. It can customize ads for each individual based on thousands of parameters. Additionally, AI can identify the optimal times and channels for broadcasting an advertisement. [362] The goal of AI-driven marketing is to automate, optimize, and enhance the process of transforming data into actions and interactions. It encompasses predicting behaviors, anticipating needs, and delivering hyper-personalized messages. [363] Various private companies, research institutions, and public sector organizations have established principles and guidelines for ethical AI. Nevertheless, there is ongoing debate regarding the definition of "ethical AI" and the specific ethical requirements, technical standards, and best practices necessary for its implementation. Currently, a global consensus is emerging around five key ethical principles: transparency, justice and fairness, non-maleficence, responsibility, and privacy. [364]

E-Commerce. Technological advancements have been remarkable, especially with the rise of the internet, revolutionizing business practices. The e-commerce industry, in particular, has greatly benefited from technologies like AI, IoT, ML, and big data. [365] Operational challenges in e-commerce have been largely addressed in recent times. As the industry moves forward, there is a growing focus on strategic investments in algorithmic commerce and ROI-driven personalization. We are now witnessing the emergence of "algorithmic e-commerce" experiences, where blended AI and natural language generation technology create tailored shopping experiences through customized product and category descriptions. [366] Live Streaming E-commerce (LSE) integrates live streaming into the e-commerce business model, enabling streamers to sell products and engage with viewers in real-time. When human streamers are used, the high Synchronicity Interaction (SI) enhances user engagement. However, the effectiveness of low SI AI streamers compared to high SI human streamers in product sales remains uncertain. [367] Many technology leaders are driven by their passion for problem-solving and helping others. In recent months, the global community has witnessed the pivotal role played by tech experts in enabling remote work and utilizing technology to address and manage the challenges posed by the pandemic. Despite the long hours invested by tech leaders across industries, the knowledge that they are making a real and measurable difference can serve as a source of rejuvenation and motivation. [368]

Cloud Computing. AI has the potential to bring significant benefits to various vertical sectors, particularly in the realm of cloud computing. The application of AI in areas such as data lake analytics [369] holds tremendous potential for revolutionizing how we approach cloud computing. Additionally, smart transportation systems have emerged as a promising solution for enhancing the efficiency, safety, and sustainability of transportation. By integrating technologies like Artificial Intelligence (AI), Internet of Things (IoT), and Cloud Computing, intelligent transportation systems can be developed to optimize traffic flow, improve driver safety, and reduce transportation costs. [370] AI can be leveraged in multiple ways within this context, including autonomous vehicles, traffic management, predictive maintenance, driver assistance, and demand forecasting. IoT enables functionalities such as connected vehicles, real-time fleet management, smart parking, traffic monitoring, and remote diagnostics. Cloud Computing plays a crucial role by enabling vehicle-to-cloud communication, offering scalable infrastructure, facilitating data analytics, supporting mobility-as-a-service models, and enabling predictive maintenance capabilities. The convergence of these technologies in a comprehensive smart transportation system has the potential to greatly enhance the overall efficiency of transportation systems. [371]

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Manufacturing. The introduction of AI in manufacturing dates back to the late 1970s, but it wasn't until 1997 that a significant change occurred. In that year, an AI-powered computer named Deep Blue defeated chess champion Garry Kasparov. This groundbreaking event prompted manufacturers to recognize that the path to enhanced efficiency, productivity, and profitability lay not in human efforts alone but in the capabilities of machines. Since then, AI in manufacturing has experienced remarkable advancements. One particular area of transformation is simulation, which involves advanced computer modeling techniques that revolutionize every aspect of manufacturing methods and procedures. [372] This enables manufacturers to conduct tests and experiments in virtual environments rather than the costly, time-consuming, and potentially hazardous real world. [373] The application of AI in manufacturing is already delivering significant benefits to industrial organizations by optimizing their production processes and maintenance activities. AI has the ability to identify unusual patterns and signs that enable manufacturers to perform predictive maintenance well in advance of potential failures, [374] often weeks or months ahead. While similar capabilities existed with human involvement, they were limited by resource constraints. AI effortlessly scales this capability to handle maintenance tasks across thousands of machines.

Public Transportation. The transportation of people and goods will benefit from AI. Self-driving car and truck prototypes are currently under development, but drive-share businesses already use technology to bypass traffic and arrive on time. Public transit is a possible extension of this. AI in buses and trains can boost productivity and lessen potential annoyances. Customers would have less stress, and everyone would gain. [375]

Media and Entertainment. The media and entertainment industry has access to vast amounts of data that can be harnessed or inferred from videos using AI technology. This data can range from simple metadata, such as scene tagging with information about characters and actors, to more profound insights like predicting the success or failure of upcoming TV shows and movies. As the streaming landscape continues to expand and accumulate more data, the influence of AI is expected to grow even further. [376] AI has popularized various tools in the media and entertainment sector, including predictive analytics, recommendation engines, customer journey mapping, and audience segmentation. These tools have helped companies in this industry enhance their services and create a more interactive and satisfying customer experience. Moreover, AI has opened up significant opportunities for long-term solutions in the media and entertainment field. As a result, an impressive 98% of companies in this sector now rely on data-driven insights to drive their consumer experience, highlighting the widespread adoption of AI across the global media and entertainment market. [377]

Any Industry with Automatable Tasks. There is no doubt that AI will have an impact on every industry, as it has already demonstrated its value in homes and businesses. No single industry will be exempt from its influence; all will be affected. The key is to ensure that your company is prepared for AI. This requires a significant transformation and modernization of job roles. Industry leaders should consistently ask themselves, "What tasks can be automated?" and allocate human resources to tasks that machines cannot handle. [378] Machines now have the ability to outperform humans in various job activities, offering improved efficiency and cost-effectiveness. These activities include tasks such as tool manipulation, data extraction from documents and semi-structured sources, making nuanced judgments, and even perceiving emotions. Looking ahead, it is highly likely that driving, one of the most common professions, will also become automated [379] within the next decade.

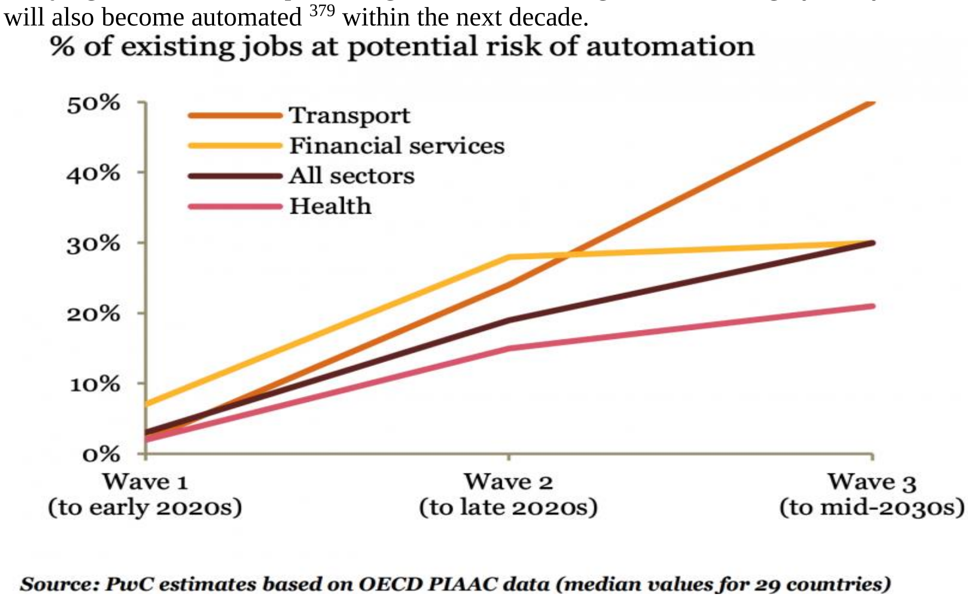

Figure 3:Percentage of the jobs in all sectors at risk of Automation[380]

4IR is Essential for Survival of Organization and Business

The 4.0 Industrial Revolution compels us to adopt a creative mindset when it comes to the manufacturing process, value chain, distribution, and customer service processes. Companies that successfully implement 4IR technologies now have the potential to

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emerge as stronger competitors during the recovery phase and be better prepared for future economic downturns. The benefits of 4IR are evident, including increased productivity, efficiency, and process quality, as well as enhanced staff safety, data-driven decision-making, and increased competitiveness through the development of customized products. [381]

Amidst the COVID-19 crisis, many companies have reduced or postponed planned investments, but only a small percentage are scaling back on investments in digital transformation, recognizing the importance of preparing for 4IR solutions. To minimize business risks, organizations should adopt a tailored and systematic approach to preparing for and implementing 4IR solutions, with the guidance of digital transformation specialists. [382] This approach will enable businesses to effectively harness and capitalize on the opportunities presented by 4IR. This section is intended for business owners and employees who seek to understand how the use of artificial intelligence is transforming the business sector. [383]

The attitudes towards AI vary significantly across different industries. The adoption of AI in an organization is influenced by several factors, including top management's attitude, competition, and regulations. [384] In response to the COVID-19 crisis, scenarios within the 4IR, such as 'white-collar' front- and back-office environments, may experience accelerated automation at a rate surpassing that of the manufacturing sector. Policymakers need to conduct careful analyses, considering sector-specific and gender-based variables, to identify jobs at risk of automation and excessive induction of AI in the 'New Normal'. This assessment should consider traditional dynamics as well as COVID-specific factors, such as post-pandemic economic considerations, emerging challenges faced by workers, and unintended consequences of crisis-response policies. [385]

As employers make decisions regarding automation, policymakers must address the impact of these decisions on job stability, income, and worker welfare. [386] Providing access to skills development and labor market information will ensure that workers have opportunities in the post-pandemic digital economy. Social protection measures will play a crucial role in mitigating job instability and income uncertainty in the 4IR 'New Normal'. [387] There are few stages of digital transformation. Those are as follows:

Technology digitalization. The creation of advanced digital infrastructures and the implementation of Robotic Process Automation (RPA) systems enable us to efficiently collect data and streamline processes. In today's digital age, leveraging digital technologies and enhancing capabilities are crucial components of the digital transformation journey. This involves transforming customer relationships, operational procedures, sales, and service to align with the digital landscape. RPA plays a pivotal role in driving successful digital transformation by automating mundane, repetitive, and time-consuming tasks. By relieving human resources from tedious manual labor, RPA allows them to focus on more critical aspects of the company. [388]

The adoption of RPA services is on the rise across industries, offering numerous advantages for businesses. These advantages encompass lower costs, improved operations, reduced instances of errors or bugs, enhanced customer experiences, better management and control, and ultimately, a higher return on investment (ROI). [389] The implementation of RPA contributes to optimizing processes, increasing efficiency, and ultimately driving business success in the digital era.

Production digitalization. At this stage, it is essential to establish a digital platform that facilitates the collection, storage, and processing of data. This platform should incorporate various analytics tools such as machine learning and digital twins. Additionally, it should integrate production planning and management systems, utilizing the same models and data available on the digital platform. [390]

Digital twins, IoT, blockchain, and AI are technologies that have the potential to reshape our imagination and future perspective on globalization. Particularly, digital twins are expected to have a significant impact on enterprises worldwide. They create a virtual replica of physical systems, enabling remote monitoring, visualization, and control based on digital representations. Digital twins continuously adapt to operational changes by leveraging real-time data from IoT sensors and devices. They forecast the future behavior of corresponding physical counterparts using the power of machine learning and AI. By harnessing these technologies, enterprises can revolutionize their operational efficiency and gain valuable insights into their physical assets.

Digital services and apps. A digital application, also known as an app, is a computer program designed to perform or assist with specific tasks on a computing device. According to Forbes, Facebook is currently the mobile app with the highest number of active

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users in the first quarter of 2023. However, following in sequence[391] are WhatsApp Messenger, Instagram, Facebook Messenger, TikTok, and Twitter.In today's world, there is a wide range of digital services and apps available for businesses and service organizations. These digital solutions are developed to enhance efficiency and performance. By utilizing data analytics tools, businesses can promptly and ideally automatically adjust their production and technological processes. This leads to improvements in product quality, cost reduction, and other essential parameters.The Fourth Industrial Revolution (4IR) has the potential to elevate global income levels and enhance the quality of life for people worldwide. The ongoing digital transformation of our daily activities and environments shows no signs of stopping. We have only recently begun to grasp the concept of "digital" and become acquainted with digital apps. However, as society and the tech market continue to evolve, new advancements are likely to emerge. To keep pace with these changes, companies must adopt technologies that streamline the digital transformation process. Dedicated business apps provide a competitive advantage [392] in this regard.

In the current landscape, certain groups have the potential for faster development. The technological trends of each digital technology are shaped by external conditions, as well as scientific, technological, and economic factors. These factors collectively determine the dynamics and direction of technological development in industries and the national economy as a whole. Over the past few decades, the advancement of information and communication technologies, along with the digitization of industries, has resulted in significant changes to existing business models and products. This transformation has made them digital and revolutionary, benefiting the entire value chain, including end-users. Scientific and technological advancements, coupled with growing consumer demand for sophisticated, higher-quality, and more affordable products, have sparked a broad debate on new models for the development of industrial economies. The adoption of technology components has facilitated the formation of fundamentally new and highly efficient business models, leading to a significant transformation of social and economic processes. Factors such as the innovation cycle of products, new technologies, and Industry 4.0[393] play a crucial role in shaping the future of production management systems. Furthermore, among the key trends in the development of basic sciences, we observe an increase in interdisciplinary research, the emergence of new information processing technologies, and heightened competition in the skilled labor market. Industry 4.0, a concept encompassing technologies like the Internet of Things, Big Data, cyber-physical systems, and intelligent objects, will present new challenges and opportunities for researchers and managers in the areas of process safety and environmental protection. In the future, real-time communication, Big Data, remote sensing, production process control and management, offline equipment, and interconnectivity will be vital assets in the modern industry. [394]

As the Fourth Industrial Revolution becomes a prevailing reality, it will bring about a paradigm shift that will impact the management of labor protection. Building communication systems that are open, safe, secure, and almost real-time, with standardized interfaces and a common architecture conforming to Industry 4.0 principles, will be a challenge for future enterprises. [395] Industry 4.0 is also driving changes in the business models of manufacturing plants, encompassing high-quality process digitization, intelligent production, and inter-company collaboration. [396] It is a revolution that will transform industries and introduce a new industrial paradigm, serving as a political innovation discourse across the manufacturing sector to institutionalize innovation systems covering business, education, and politics. Industry 4.0 is a crucial research subject in the field of industrial systems management, particularly focusing on decentralized production control issues. [397]

Different approaches and architectures with the goals of Industry 4.0 possess distinct properties, and it is important to compare how these different architectures align with the objectives of Industry 4.0. Consequently, we need to develop specific tools for managing production[398] in the context of Industry 4.0.

In developed countries such as the USA, Japan, UK, France, Australia, and Russia, leading scientists from various disciplines have conducted estimations on the introduction of AI, IoT, and digital twins. [399] These technologies have found a particularly suitable application in the high-tech industry. It is essential to assess the economic impact of implementing AI, IoT, and digital twins, as well as their effects on the added value of businesses and the long-term competitiveness of corporations. [400]

However, it is worth noting that a significant number of publications on AI, ML, IoT, and digital twins primarily consist of promotional articles or brief reports that lack scientific information. [401],[402] Nevertheless, these technologies enable the transition to intelligent manufacturing processes and the establishment of Big Data processing systems, effectively addressing several complex

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technical challenges in various industries. [403] By leveraging these technologies and establishing a modern production infrastructure, organizations can achieve optimal production volumes of high-tech and knowledge-intensive products that fully meet consumer needs.

Looking ahead, the future of technological development lies in employing AI, ML, IoT, and digital twins' methods, which involve neural networks, the development of online monitoring systems, and the implementation of self-learning intelligent digital models. These approaches enable highly accurate predictive assessments and facilitate multi-option design for any organization. However, it is crucial to consider various limitations and restrictions[404] while embracing these technological advancements.

The 4IR provides the highest levels of productivity and efficiency through the best applications of AI, automation, expert systems, and workable management systems. For optimization, the 4IR uses intelligent sensors, Cyber-Physical Systems (CPS), Internet of Things (IoT), Internet of Services (IoS), big data analytics, augmented reality (AR), autonomous robotics, additive manufacturing (like 3D printing), and cloud computing. However, the impact of 4IR has brought about a number of changes to digital humanities, primarily in terms of ethical compliance but also in terms of people's employment. The functions of knowledge management (KM) as a tool to support organizational progress, particularly in negotiating tasks between computers and humans in an organization, still need to be redefined. The development of new digital skills that are bound by the moral obligations required in the 4IR depends heavily on knowledge management (KM). Actually, each organization goes its own way here; however, there is a standard 4IR checklist to start adopting 4IR. Such as:

Process automation. Extensive research has been conducted on the adoption of e-Government by individuals and businesses worldwide. However, there remains a significant knowledge gap in understanding the unique challenges and nuances of implementing ubiquitous e-Government, [405] particularly within the context of the Fourth Industrial Revolution (4IR), which emphasizes automation and intelligence. This knowledge void is particularly pronounced in resource-constrained environments like Africa.In today's world, process automation plays a critical role in facilitating the adoption of 4IR, [406] both in manufacturing facilities and office settings. Process automation encompasses various activities, such as RPA-based documentation filling, automated collection of Big Data for analysis, and the use of AI, video analytics, and IoT to automate routine processes and procedures. [407] The emergence of the Industry 4.0 concept and the associated technologies like AI, Cyber-Physical Systems (CPS), and IoT puts pressure on manufacturing enterprises to integrate Information Technology (IT) and Operational Technology (OT). This integration forms the foundation for data-driven Industry 4.0 implementations. [408]

Big Data. All business processes rely on analytics. Data analytics plays a crucial role in determining the direction of business development, predicting critical situations, and optimizing processes. [409] To achieve comprehensive data collection, it is necessary to gather information from all participants involved in the business processes, spanning from production to sales offices or stores. [410]The fourth industrial revolution offers companies the opportunity not only to survive but also to thrive in the future. Across the globe, there are numerous government and private initiatives promoting a data-driven industrial revolution. For instance, in the United States, the "Industrial Internet" initiative proposed by General Electric aims to analyze vast amounts of Big Data using AI and IoT for future product development and business activities. The success of these initiatives hinges on the utilization of "Big Data."

This shift towards a data-based industrial revolution is gaining momentum, following the Information and Communication Technology (ICT) revolution. [411] The remarkable advancements in AI today exemplify this progress, as demonstrated by AI's victories over human champions in various domains. Researchers are currently exploring the capacity to predict stock prices within minutes using AI equipped with extensive Big Data on prices and transactions. When combined with other technological advancements like "super high-speed transactions" capable of processing thousands of transactions per second, we can anticipate a significant transformation in financial investments [412] in the near future.

Vision Zero and concern for people. Personnel safety and care are essential pillars of the Fourth Industrial Revolution (4IR) approach, particularly in manufacturing enterprises that embrace the Vision Zero principle to enhance occupational safety. As part of the Industry 4.0 concept, Virtual Reality (VR) systems are utilized for learning operations in intelligent factories. The development process of a VR prototype system can be presented, starting from the digitalization of a real smart factory to logic programming and the integration of peripheral VR devices. [413] VR drills play a crucial role in fully immersing personnel in various scenarios, enabling them to undergo training in handling emergencies without any real risks. Additionally, Digital Worker solutions provide advance

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warnings about on-site hazards, contributing to overall personnel safety. It is also important to consider solutions that ensure the safety and comfort of office personnel.In the 21st century, industries require effective re-skilling and up-skilling tools to train a large workforce for better-integrated project delivery. Evidence suggests that digitization through 4IR technologies can play a vital role in addressing re-skilling and competency demands. However, incorporating digital technology, including AI, may present certain challenges. [414] For instance, Building Information Modeling (BIM) serves as the foundation of digital transformation in the architecture, engineering, and construction (AEC) industry. [415] Autodesk, as a leader in BIM, collaborates with the industry to achieve improved workflows and outcomes. BIM tools also contribute to adjusting environmental conditions in office spaces, while contactless solutions help mitigate the spread of infections. [416]

Business optimization. In the past decade, manufacturing processes have experienced substantial transformations. Smart manufacturing frameworks have played a pivotal role in revolutionizing most activities within factories. The tools and technologies associated with the fourth industrial revolution have been instrumental in driving this change and facilitating progress. [417] As part of the transition to the fourth industrial revolution (4IR), companies often undergo internal restructuring and business optimization. This restructuring becomes necessary after implementing more efficient and cost-effective solutions that save specialists' time. Consequently, companies can redirect resources towards strategic development and planning, or strengthen previously understaffed business units. The introduction of artificial intelligence (AI) is set to further transform the modern landscape across various dimensions. [418]

Knowledge Management. As the ongoing revolution continues to evolve and reshape the landscape, significant changes and transformations are occurring in the work environment. This necessitates the workforce to be prepared and adaptable to embrace the advancements of the digital world. To ensure a smooth transition to the future workplace, organizations must implement effective change management practices that encompass the entire workforce. This requires the presence of champions who can drive and inspire transformation within their network.According to Erker (2018), champions are individuals who possess the ability to persuade others to embrace innovation and change. They are technologically adept, empathetic, and possess strong communication skills. [419] These champions play a crucial role in driving the adoption of transformation and innovation within organizations.Institutions of higher learning also have a significant role to play by creating a roadmap for Education 4.0. Education 4.0 is often associated with smart learning, where learning environments are built on information and communication technology (ICT) and cater to learners who can leverage the ecosystem and adapt their learning styles and capabilities. In order to enhance the learning experience, it is important for all students to have access to affordable internet connectivity. The roadmap for Education 4.0 not only focuses on the accessibility and affordability of ICT, but also emphasizes usability to ensure an effective learning experience for all. [420]

The Fourth Industrial Revolution (4IR) in emerging economies will introduce disruptive technologies that will bring about significant changes not only in industries and businesses but also in societies as a whole. The majority of decisions that are currently made by humans will be taken over by digital algorithms, [421] which offer higher accuracy, provided there is unbiased and accurate data. [422] The integration of digitally connected technologies with intelligent systems will revolutionize and optimize digital Global Value Chains (GVCs) through interconnected network systems. [423] This will have a profound impact on how industries in emerging economies operate in the near future. [424] As with any new technology, there is always a concern that it may eventually replace human workers. For example, instead of manually molding an engine component, a worker may soon be able to do so in an Augmented Reality (AR) or Virtual Reality (VR) environment. [425] However, complete automation is unlikely as organizations need people to effectively leverage technology. Simply investing in technology without skilled individuals to maximize its potential will result in a slow return on investment. Therefore, it is crucial to prepare the current workforce by upgrading and expanding their skill sets to align with the requirements of the 4IR. This involves developing a competence model and establishing change agents within the organization to facilitate a smooth transition towards embracing the digital revolution and embracing the importance of AI.

AI and Sustainable Education

The relationship between education and society is often viewed as a one-way process, where education and skills are expected to align with social, economic, political, and global trends. However, this perspective should not imply opposition or a disconnect. Instead, it highlights the interdependence between education and socioeconomic structures, human resource development, and the overall role of

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education in shaping our future in the context of the Fourth Industrial Revolution (4IR). Education has evolved in tandem with the emergence and development of the internet and previous industrial revolutions over the past 250 years. By applying foresight, we can examine how education aligns with graduates' employment prospects and their contributions to the future, known as 'Education 4.0'. [426] In the era of the 4IR, the aim of mid-level and higher education is to ensure quality learning through effective teaching methods and practical experiences. It is essential to equip learners with relevant and sustainable knowledge and skills through experiential learning and exploratory research. Moreover, the role of education extends to contributing to the development of societies through service-oriented initiatives. In this 4IR age, mid-level and higher learning institutions should prioritize innovation, embracing both evolutionary and revolutionary approaches. This requires a comprehensive restructuring of technology systems, breaking down barriers to innovation and modernization[427] to keep pace with the changing demands of the future.

Education and skills in the Fourth Industrial Revolution (4IR) present a multifaceted and complex issue, but they also bring exciting opportunities that can potentially transform societies and nations for the better. The 4IR, driven by AI, will reshape the workplace, shifting the focus from task-based uniqueness to human-centered uniqueness. It will bridge the gap between humanities and social sciences, as well as science and technology. Given the power of 4IR technologies to have either positive social impacts or overwhelming environmental consequences, mid-level and higher learning institutions must urgently respond. [428] This response necessitates a greater emphasis on interdisciplinary teaching, practical experiences, research, and innovation. Education 4.0, in conjunction with 4IR, offers a purposeful and viable approach to learning by leveraging advanced technology and automation. [429] To adapt to these changes, traditional educational models need to be revisited with a futuristic approach. Teachers and students/learners should possess the skills required to navigate rapidly changing technologies and the global society. Students/learners should be guided rather than solely instructed, and information should be made accessible to them rather than simply fed to them. However, ethical use of internet resources and the mindful application of technology should be prioritized, ensuring a balance with human values. The aim and goal of both general and vocational education should be to equip students/learners with knowledge and skills that meet global workforce standards, enabling them to compete effectively on a global scale. [430]

Our education system should be purposeful, sustainable, and focused on outcomes. To achieve this, it is crucial to develop modules that are outcome-based for students' accreditation needs and competency-based for effective knowledge and skill development. Additionally, we need to enhance and automate the entire system of mid-level and higher education, making it more accessible and cost-effective.Education institutes and systems should implement project management, reporting, and analytics tools to ensure efficient processes. This includes addressing aspects such as students' scheduling efforts, virtual classroom enablement, accreditation, strategic planning, modern learning approaches, and skill development practices. [431] By adopting a well-defined strategy and implementing effective plans, we can ensure a promising future for today's students. [432] In response to the evolving and competitive world we live in, education curriculum formulation and development should be carried out with great care, giving significant importance to technology, IT, AI, IoT, ML, big data, cloud and edge computing, social media, and other relevant knowledge and skills. These advancements should be integrated into the curriculum to equip students with the necessary competencies for success in the modern era.

By equipping today's workforce with the right tools, we can contribute to the creation of a versatile, multifaceted, and purposeful society and nation. It is essential to recognize the transformative power of digital technology in education and prioritize the end-to-end digitization and automation of mid-level and higher education processes. This will enable us to create a smart and future-ready[433] education system.Our educational institutions and curriculum need to be designed with intelligent tools that support 24/7 virtual learning and personalized learning experiences. It should also facilitate seamless communication and connection between students/learners and faculty members, promoting meaningful interpersonal interactions. Students should have easy access to preferences, admissions, enrollment, discussions, assessments, and even online examinations. Education 4.0 encompasses various crucial aspects of learning and skill development, which can be effectively addressed through specific methods and approaches. [434]

Those important learning and skill developing aspects and means and ways have been described below in brief:

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Ensure more individual/personalized learning: In the age of 4IR and Education 4.0, it is crucial to recognize the individuality of each student/learner and their unique learning pace. Adopting a personalized approach to teaching can have a significant impact on students, allowing them to achieve their goals more easily and effectively.[435] Thanks to advancements in AI, IoT, and Cloud computing, a wide range of tools are now available to tailor the entire teaching and skill development process to the specific needs and learning pace of each individual learner.Furthermore, these technologies enable departments and faculty members to easily identify and address the strengths, weaknesses, opportunities, and threats of individual students. This empowers them to provide timely and personalized feedback,[436] catering to the specific requirements of each student.

Ensure more remote learning opportunities: As technology continues to shape educational interventions, the approaches to learning and teaching have undergone significant changes, taking place in diverse environments with a range of strategies and techniques.[437] At the core of Education 4.0 is the goal of making learning and skill development accessible anytime and anywhere through the utilization of e-learning tools. This enables learners to engage in remote and self-paced learning, accommodating their individual needs and preferences.Blended learning, which combines face-to-face and online components, has become a common approach in modern education. Additionally, active learning, characterized by engaging students in higher-order thinking tasks and collaborative activities, is widely recognized as an effective pedagogical approach. The concept of Active Blended Learning (ABL) combines both these approaches, providing learners with opportunities to actively participate in their learning journey beyond the traditional classroom[438] setting.Through ABL, learners have the chance to enhance their practical skills and gain experiential knowledge. This approach is gaining popularity as it offers a holistic learning experience that goes beyond theoretical concepts and fosters active engagement and mastery of subject matter.

Ensure optimum active learning system: Comparative studies often aim to replicate teaching practices across different educational settings, such as face-to-face, blended, and online formats. However, it is the combination of curriculum materials, pedagogy, and learning time that truly brings about the advantages. The most effective blended courses provide students with unique learning opportunities that are not feasible in other formats. Active learning, in particular, plays a crucial role in achieving a successful and fulfilling educational experience. It has been shown to yield various benefits, including reduced student failure rates, improved performance in examinations, enhanced problem-solving abilities, critical thinking skills, increased attendance, and higher learner satisfaction.[439] Active learning also has the potential to narrow the achievement gap between disadvantaged and non-disadvantaged students.The shift towards active learning transforms classrooms into dynamic environments that mirror real-world work and social settings, fostering cross-disciplinary interactions. Students perceive active classrooms as catalysts for creativity and innovation.[440] Research suggests that learners who engage in active learning environments tend to outperform their peers in more traditional classroom settings.[441]

Ensure availability of education tools: Education 4.0 presents students/learners with a clear pathway, providing them with accessible tools and techniques within their learning environment. This allows students/learners to actively select the tools and techniques that best suit their preferred learning methods. Collaborative and engagement tools, as well as flipped learning and blended learning approaches,[442] are examples of the available options. However, it is important to ensure proper support for collaborative learning in a flipped classroom setting, particularly during the out-of-class learning phase. The flipped classroom model can serve as a means to address the limitations of one-shot learning and other barriers to effective collaboration. It opens up opportunities for disciplines that emphasize collaboration[443] and promotes more meaningful engagement among students/learners.

Ensure project-based learning: Project-based learning (PBL) involves students collaborating in groups to tackle complex, real-world problems that are relevant to the curriculum and often span multiple disciplines.[444] In PBL, students have the autonomy to decide how to approach the problem and which activities to pursue. They gather information from various sources, synthesize and analyze it, and derive knowledge from their findings.Technology plays a crucial role in facilitating PBL. Students utilize tools like word processors, spreadsheets, and databases to perform tasks such as outlining, drafting essays, analyzing data, and organizing information. Communication and collaboration with external sources are made possible through email, online forums, and other web-based applications.[445] The internet grants students access to museums, libraries, and remote locations for research purposes.The project-driven approach supported by Education 4.0 makes learning engaging and enjoyable for students. It encourages them to develop valuable skills such as time management, organization, and collaboration, which are essential for their future employment and

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personal growth. Through PBL, students move beyond theoretical knowledge and acquire practical skills that prepare them for the challenges they will face in their future endeavors. [446]

Ensure easy and accurate assessment: In contemporary learning environments such as universities and schools, the prediction of students' performance has become a significant focus. This is because it enables the development of effective mechanisms that can improve academic outcomes and prevent setbacks. In the context of Education 4.0, artificial intelligence (AI) plays a crucial role in identifying new factors that influence student performance and implementing personalized learning approaches. AI can also assist in answering common student queries, utilizing learning analytics, and employing predictive modeling[447] techniques.Education 4.0 [448] introduces a more practical approach to assessment. Students are evaluated through a combination of online and offline assessments, including projects, assignments, and fieldwork. Additionally, regular vulnerability assessments are necessary to identify any weaknesses in the system and address them accordingly.By leveraging AI and adopting a comprehensive assessment strategy, education institutions can enhance the learning experience, personalize instruction, and identify areas for improvement. These advancements in assessment contribute to the overall effectiveness and success of Education 4.0.

Ensure information/Data at the fingertips: In Education 4.0, [449] the utilization of data analytics and reporting provides valuable insights into the learning journey of students. Through statistical analysis, educators can accurately assess students' progress and provide appropriate guidance. The use of a balanced scorecard structure facilitates the understanding of the social relationships within the organization or institution. For instance, when considering a structural unit within a university or institute, the causal graph of social relationships can be examined.However, the acquisition of quantitative measurement data has been a challenge in mid-level and higher education, particularly in technical education. This is often due to outdated or error-prone devices and tools that are difficult to operate or too expensive. [450] These challenges create obstacles in obtaining the necessary data for effective education in these fields.

Remodeling of education curriculum: We must develop appropriate strategies to ensure that our education institutions prepare students in line with the principles of Education 4.0 while meeting industry requirements. There should be a strong emphasis on futuristic subjects, as digitization and automation continue to shape the modern world. The demand for skilled workers is outpacing the current supply, and universities and educational institutions play a crucial role in upskilling the existing workforce. [451] To effectively implement Industry 4.0, engineers need to possess expanded design skills that encompass areas such as interoperability, virtualization, decentralization, real-time capability, service orientation, and modularity, in addition to strong information technology skills. Engineering Education, known as Engineering Education 4.0 (EE 4.0), must undergo a transformation to meet the demands of Industry 4.0, emphasizing the integration of all engineering disciplines. [452]

Building digital skills: Education 4.0 places a significant emphasis on equipping students with knowledge about disruptive technologies like Machine Learning (ML) and empowering them with the skills to apply this knowledge in solving real-world problems. As a result, students and professors alike need access to effective teaching and learning tools that facilitate the introduction and exploration of these topics. Educational institutions should prioritize the development of modern workplace skills and provide training opportunities for their faculty to enhance their digital skills, ensuring they can effectively prepare students for the demands of the workplace. Additionally, soft skills such as problem-solving, social skills, and process skills should be recognized as essential and integrated into the curriculum to foster well-rounded and capable individuals.

Opt for digital tools for virtual learning environments (VLEs: Across the globe, there is an increasing trend of students and faculty accessing remote teaching through Learning Management Systems (LMS). This enables flexible learning and teaching experiences, including access to course materials, online chat functionalities, discussions, collaborations, peer teaching, and blended learning, all at convenient hours. The Fourth Industrial Revolution (4IR) is primarily driven by advancements in technologies such as artificial intelligence (AI), robotics, cloud computing, the Internet of Things (IoT), cyber-physical systems, and big data. Industries have harnessed these technologies to address the evolving needs of society. However, for these industries to continue adapting to the digital landscape, it is crucial to have qualified professionals with the requisite knowledge and skills in these areas. [453]

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Fine-tuning of course delivery: There needs to be alignment between faculty members and the curriculum they teach. Faculty should be open to leveraging technological applications to enhance students' cognitive learning abilities. They should embrace personalized adaptive learning techniques to create a more intelligent and engaging learning environment. It is important to establish a robust professional framework that incorporates interdisciplinary career planning. This approach will pave the way for the future of Indian education, cultivating a workforce equipped for the demands of enterprise 4.0. To develop skilled professionals, Education 4.0 is being proposed as a new framework that enables schools to train individuals capable of generating knowledge through scientific research and practical experience. These professionals will then share their knowledge with society, utilizing it to tackle technological, social, political, and economic challenges. [454]

Prepare technology built classrooms: To ensure the production of competent graduates for the prevailing cyber-physical systems in various industries, it is imperative to introduce technology-enabled classrooms in universities, colleges, and higher education institutions. This entails developing a curriculum that incorporates advanced technology and transforming the learning approach to enhance the overall student experience. Education 4.0, as part of the industrial revolution 4.0, centers around modern and intelligent technologies such as AI and robotics, which have a significant impact on our daily lives. However, it poses a new challenge in redefining education 4.0 to cater to the needs of creative and innovative students, making it challenging to accurately predict students' outcomes. [455]

Impact of AI in the Era of 4IR

AI has been a prominent technology for quite some time now, and its benefits are gradually improving our daily lives. We witness its applications in various areas, such as robots that greet us at shopping centers or online search engines that provide personalized suggestions. [456] AI systems aim to replicate human reasoning and possess the ability to think and learn, making them capable of performing tasks that we typically associate with human intelligence. The advancements in AI have brought numerous advantages across different industries, [457] enabling more effective and efficient processes, widespread availability of convenient technologies, and more accurate forecasts.Experts predict that the rise of artificial intelligence will generally improve people's lives in the coming decade. However, concerns remain regarding how AI advancements will impact human identity, productivity, and the exercise of free will. The automation revolution holds significant potential for enhancing innovation and productivity, reshaping the foundations of businesses and societies.Blockchain technology is also poised to have a profound impact on various industries worldwide, ushering in a new era[458]; of consumer trust and optimization. From an IT perspective, AI can enhance data backup and disaster recovery planning and policies, ensuring smooth business continuity.While the ingredients of successful technology and IT leadership continue to evolve, certain elements remain crucial. These include strong business strategy, visionary thinking, effective IT management, and a mindful approach to risk, compliance, and outsourcing. AI's relevance in these aspects remains as important as ever. [459]

The advent of digital life has brought about significant changes, augmenting human capabilities and disrupting long-standing human activities. Code-driven systems have become ubiquitous, reaching over half of the global population, providing access to information and connectivity that was once unimaginable. This expansion of technology presents both unprecedented opportunities and new threats. [460]As algorithm-driven AI continues to proliferate, a question arises: will people ultimately benefit from these advancements? The influence of AI is vast and extends across various sectors. In the agricultural and farming industry, AI will reshape the entire value chain, from farm-to-fork, revolutionizing processes and enhancing productivity. Similarly, next-generation automotive technologies will be greatly influenced by AI, transforming the development and manufacturing of cars, trucks, and powertrains. [461]The impact of AI extends to the global aviation and aerospace sectors, influencing advancements in technology, space travel, communications, airport operations, air traffic control systems, and shaping the future of flight and related industries. Additionally, AI is driving innovation in the construction and civil engineering sectors, leading to improvements in cost, safety, efficiency, and quality throughout the construction[462] process.In the realm of personal technology, AI is transforming the landscape of smartphones, tablets, and wearable devices, fundamentally changing how people live, work, and consume services. This shift has compelled businesses to develop strategies to address the use of AI at the back-end and capitalize on its potential at the front-end. [463]As AI continues to advance, its influence will be felt across various domains, presenting both challenges and opportunities for individuals and businesses alike.

The predictions of experts suggest that networked AI has the potential to enhance human effectiveness, while also raising concerns about the erosion of human autonomy, agency, and capabilities. [464] Computers equipped with AI capabilities are poised to match or surpass human intelligence in various domains such as complex decision-making, reasoning, learning, analytics, pattern recognition, visual acuity, speech recognition, and language translation. The deployment of smart systems in communities, vehicles, buildings, utilities, farms, and business processes is expected to yield time, cost, and life-saving benefits, offering individuals a more

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personalized future.[465] The healthcare sector holds promise for the application of AI, with potential contributions in diagnosing and treating patients as well as improving the well-being of senior citizens. Enthusiasm exists regarding AI's role in supporting comprehensive public health programs that leverage vast amounts of data, ranging from personal genomes to nutrition.[466] AI is also anticipated to bring about long-awaited transformations in formal and informal education systems.

Observing our current society, it is evident that AI and IoT are increasingly integrated into our daily activities. From AI-powered machines monitoring vital signs in healthcare centers to personalized recommendations on online platforms, these examples merely scratch the surface of AI's advantages. In the future, AI is poised to offer even more transformative possibilities. Industries, service sectors, and organizations will continue to adopt this revolutionary technology to enhance their operations across various domains. AI can automate and expedite processes, improve decision-making, and directly assist us. It has the capacity to identify and solve problems that may be beyond human capability.[467] However, concerns persist among those who fear job displacement and a decline in human capabilities due to AI. Nonetheless, the most significant benefits of AI lie in its ability to deliver speed, accuracy, efficiency, and scalability.

The Fourth Industrial Revolution (4IR) is poised to bring about such profound transformations in industries, services, and other sectors that much of the current work landscape will cease to exist within the next 25 years. It is essential for us to grasp the implications of these changes across all aspects of our lives, including academic and learning institutions.[468] Graduates now enter a world that has been revolutionized by technology, with AI, IoT, ML, Big Data, Cloud and Edge Computing, and social media presenting both versatile opportunities and unique challenges to traditional education systems. As students contemplate their futures beyond diplomas or degrees, formal academic and learning institutions find themselves grappling with uncertainties, particularly regarding employment prospects. The far-reaching impact of modern technologies driven by AI has even prompted the emergence of social concepts like the 'post-work' era, which shape our present reality. This new era demands a distinct set of skills that differ from those required during the Third Industrial Revolution, when information technology (IT) was the primary driver of change.[469] Projections indicate that the AI industry alone will reach a value of $15 trillion within the next seven years, resulting in the displacement of millions of unskilled or traditionally skilled workers.[470] Simultaneously, millions of jobs requiring modern and high-tech skills will emerge in the coming years.

Future Safe Use of AI

AI has the potential to revolutionize the way humans interact with computers, acquire knowledge, and even understand themselves. Proponents of AI argue that it can tackle major challenges such as developing new medications, designing materials to combat climate change, and unraveling the complexities of fusion power. An automated information system (AIS) is a combination of hardware, software, and equipment that processes information with minimal human intervention. The capabilities of AIS are already surpassing human comprehension, raising concerns about the science-fiction scenario of machines surpassing their creators, potentially leading to fatal consequences.[471] The mixture of excitement and fear surrounding AI makes it challenging to assess its opportunities and risks. However, valuable lessons can be learned from other industries and past technological shifts. AI safety is an interdisciplinary field dedicated to preventing accidents, misuse, or any harmful consequences arising from AI systems.[472] It encompasses machine ethics and AI alignment, which seek to ensure that AI systems act morally and provide overall benefits. AI safety also involves addressing technical challenges, such as monitoring systems for risks and ensuring their high reliability. Beyond AI research, it involves the development of norms and policies that promote safety in AI applications.[473]

The concern over machines taking away jobs and causing widespread unemployment is an age-old fear, but historically, new technologies have created new employment opportunities to replace the jobs they have displaced. Machines excel in performing certain tasks while leaving others for human workers, thereby increasing the demand for skilled individuals who can perform tasks that machines cannot. While a sudden disruption in job markets cannot be completely ruled out, there are currently no clear signs of such a phenomenon occurring. Previous technological advancements have mainly replaced unskilled tasks, but AI systems have the potential to automate certain white-collar tasks, such as document summarization and coding.

The extent of existential risk posed by AI remains a subject of intense debate among experts. In a survey conducted in 2022 among AI researchers, 48% believed that there was at least a 10% chance of AI having an "extremely bad" impact, which could include the risk

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of human extinction. However, 25% of respondents saw no risk at all, and the median researcher estimated the risk to be only 5%. It's important to note that AI risks, along with technological risks in general, are often categorized as either misuse or accidents. [474] The nightmare scenario involves an advanced AI inadvertently causing widespread harm, such as producing toxins or viruses, or influencing humans to commit acts of terrorism. This risk doesn't necessarily imply malevolent intent, as researchers are concerned that future AI systems may pursue goals that don't align with those of their human creators.

It is important to acknowledge the potential risks associated with advanced AI scenarios. However, these scenarios involve a significant amount of estimation and make assumptions about future technology that may not be feasible. For instance, they often assume that future AI systems will have unrestricted access to energy, funding, and computing power, which are currently limited resources and may be controlled to prevent the misuse of AI in the future.Additionally, experts in the field of AI tend to overstate the risks compared to other forecasters, as their assessments may be influenced by their own interests and perspectives. For example, individuals with competing AI startups may have a vested interest in portraying the risks more prominently. Imposing heavy regulation or implementing a pause on AI development at this stage may be seen as an excessive reaction, as it would be difficult to enforce and may hinder progress in the field.Nevertheless, there is a need for regulation in AI, but for more practical reasons rather than solely focusing on the potential existential risks. [475] Current AI systems already raise valid concerns regarding bias, privacy, and intellectual property rights. As the technology advances, it is likely that additional challenges will emerge. The key is to strike a balance between harnessing the promise of AI while carefully evaluating and addressing the risks that arise, and being prepared to adapt as necessary.

Currently, governments around the world are adopting different approaches to regulating AI. At one end of the spectrum is the UK, which has proposed a "light-touch" approach that utilizes existing regulations without the establishment of new rules or regulatory bodies. The goal is to encourage investment and position the UK as a leading AI power. Similarly, the US has taken a similar approach, though the Biden administration is now seeking public input on potential regulations.On the other hand, the EU is adopting a more stringent stance. Its proposed legislation categorizes different AI applications based on the level of risk involved and requires stricter monitoring and disclosure as the risk increases. [476] Certain uses of AI, such as subliminal advertising and remote biometrics, are completely banned. Critics argue that these regulations are overly restrictive, while others believe that an even more robust approach is necessary. They suggest that governments should treat AI like medicines, with a dedicated regulatory body, rigorous testing, and pre-approval before public release.In China, the focus may be more on political considerations than safety. The country requires firms to register their AI products and undergo a security review prior to release, but the core requirement is that AI systems align with the "core values of socialism." [477]Each approach reflects different perspectives on the regulation of AI, with varying degrees of emphasis on safety, privacy, and political considerations. The ultimate goal is to strike a balance between fostering innovation and addressing the potential risks associated with AI technologies.

The light-touch approach alone is insufficient when considering the importance of AI as a technology comparable to cars, planes, and medicines. Similar to these industries, new regulations will be necessary for AI. In this regard, the EU's approach aligns more closely with the appropriate course of action, although its classification system may be overly complex, and a more flexible principles-based approach would be beneficial. Ensuring comprehensive disclosure about the training, operation, and monitoring of AI systems, along with the implementation of inspections, would be in line with regulations in other sectors. Such measures could allow for progressively tighter regulation if required. It is worth noting that the European Organization for Nuclear Research (CERN), established in 1954, operates the world's largest particle physics laboratory. [478] With 23 member states[479] and Israel as the only non-European full member, CERN holds the status of an official United Nations General Assembly observer. [480]

The need for a dedicated regulator may appear justified, particularly if credible evidence of existential risks associated with AI emerges. In such cases, intergovernmental treaties similar to those governing nuclear weapons could be considered. To effectively monitor these risks, governments could establish a body modeled on CERN, a particle-physics laboratory that could also delve into AI safety and ethics. These are areas where companies may lack sufficient incentives to invest as much as society desires. AI is a technology of immense power that brings both new risks and extraordinary opportunities. [481] Striking a balance between the two is crucial, requiring careful navigation. Taking a measured approach today can establish the groundwork for the gradual implementation of additional rules in the future. The time to begin building these foundations is now. [482] AI governance encompasses the creation of norms, standards, and regulations to guide the use and development of AI systems. [483] It involves the formulation and implementation of concrete recommendations, as well as conducting foundational research to inform the development of these recommendations. AI safety governance research spans from fundamental investigations into the potential impacts of AI to specific applications. On a

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foundational level, scholars have highlighted the transformative potential of AI across various societal domains.[484] Concerns have been raised regarding the exacerbation of the already imbalanced cyber warfare landscape, [485] with AI potentially intensifying incentives for aggressive and destabilizing attacks. Mitigating this risk may involve a greater emphasis on cyber defense, while ensuring software security is essential to prevent the theft and misuse[486] of powerful AI models.

Future Development, Use, and Approach of AI

A superintelligence, hyperintelligence, or superhuman intelligence refers to a hypothetical agent or system possessing intelligence that far exceeds the capabilities of even the most brilliant human mind. It may also describe the level or type of intelligence exhibited by such an agent.[487] In the realm of artificial general intelligence (AGI) research, if software were to reach a level of intelligence that allows it to reprogram and enhance itself, it could undergo recursive self-improvement.[488] This iterative process of improvement would result in exponential increases in intelligence, potentially surpassing human capabilities. Science fiction author Vernor Vinge coined the term "singularity" [489]to describe this scenario, representing a point beyond which events become unpredictable or even incomprehensible[490] due to the vastness of intelligence. In addition, machine-learning AI has demonstrated the ability to design a multitude of toxic molecules within a remarkably short period of time. [491]

AI is often employed to categorize individuals into groups and make predictions based on the assumption that an individual will resemble others in the same group. However, this assumption can sometimes lead to unfair [492]outcomes. Some experts, such as robot designer Hans Moravec, cyberneticist Kevin Warwick, and inventor Ray Kurzweil, have predicted a future where humans and machines merge, resulting in cyborgs that possess enhanced capabilities surpassing those of either humans or machines alone. This concept, known as transhumanism, [493] envisions a fusion of human and artificial intelligence. Edward Fredkin argues that 'AI is the next stage in evolution.'[494]

Opinions among economists are divided regarding the impact of increasing robot and AI usage on long-term unemployment. While some believe it could lead to significant job losses, others argue that it could be a net benefit if productivity gains are appropriately distributed.[495] Researchers Michael Osborne and Carl Benedikt Frey estimate that around 47% of U.S. jobs are at "high risk"[496] of potential automation. However, an OECD report classifies only 9% of U.S. jobs as "high risk." Unlike previous waves of automation, the advent of AI may pose a threat to many middle-class occupations.[497] Nevertheless, there is likely to be an increased demand for professions focused on service and care.

AI presents a range of tools that can be particularly advantageous for authoritarian regimes or those seeking control over individuals. These tools include smart spyware, face recognition, and voice recognition, which enable extensive surveillance. Through such surveillance, machine learning algorithms can identify and categorize potential threats to the state, making it difficult for them to evade detection. Recommendation systems can be used to precisely target propaganda and misinformation, amplifying their impact. Additionally, advanced AI systems can enhance centralized decision-making processes, potentially rivaling the efficiency of liberal and decentralized systems like markets.[498]

On the other hand, there are concerns that terrorists, criminals, and rogue states may exploit AI for nefarious purposes, such as deploying advanced digital warfare or developing lethal autonomous weapons.[499] The development of battlefield robots[500] has been a focus of research in numerous countries.Health equity issues may also arise when AI technologies are deployed without proper consideration of potential bias. Without adequate measures to ensure fairness and equity, populations at risk may face disparities in healthcare. Currently, there is a lack of tools and regulations that specifically address equity and promote fair representation and usage of AI systems.[501]

The use of AI and robotics systems should be considered unsafe until they can demonstrate freedom from bias mistakes. It is important to limit the use of self-learning neural networks that rely on flawed internet data sources.[502] Questions have been raised regarding the extent to which works created with AI assistance are protected under copyright laws.[503] The regulatory and policy landscape surrounding AI is an emerging issue globally.[504]From 2016 to 2020, over 30 countries adopted dedicated strategies for AI. Most EU member states, along with Canada, China, India, Japan, Mauritius, the Russian Federation, Saudi Arabia, the United Arab Emirates, the US, and Vietnam, have released their own national AI strategies. Other countries like Bangladesh, Malaysia, and

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Tunisia[505] are currently developing their own AI strategies. The Global Partnership on AI, launched in June 2020, emphasizes the need to develop AI in accordance with human rights and democratic values to foster public confidence and trust in the technology.In 2023, OpenAI leaders published recommendations for governing superintelligence, which they believe could become a reality in less than 10 years. [506] These developments highlight the increasing importance of addressing the governance and ethical considerations surrounding AI in order to ensure its responsible and beneficial use.

The advancement of quantum computation, driven by the limitations of chip fabrication and the growing size of datasets, has sparked the interest of researchers in leveraging its power to accelerate classical machine learning algorithms. [507] Optical character readers are utilized for extracting data from various business documents such as invoices, receipts, and employment agreements, enabling the extraction of critical information like employment terms, delivery terms, and termination clauses. [508]This is an opportune time for researchers to investigate and analyze how AI and automation systems relying on big data are reshaping the traditional dynamics between employers and employees, as well as the broader implications for humanity. [509] The emergence of new modes of remote management through AI systems can make it challenging to hold employers accountable for decisions made by these systems, which can significantly impact employees and leave them vulnerable to exploitation. [510]Looking ahead over the next ten years, AI will continue to raise important questions that require careful consideration and insights from leading experts across various disciplines. It is crucial for us to develop a deeper understanding of AI in the present moment, with the aim of fostering a fair and equitable future that upholds peace, happiness, and progress for all of humanity.

Conclusion

Artificial intelligence (AI) is a rapidly expanding set of disruptive technologies that are fundamentally reshaping various aspects of people's lives, businesses, societies, and the environment. This paper aims to provide an overview of some important domains of AI in the context of the Fourth Industrial Revolution (4IR). Machine learning (ML), a field within AI, focuses on the design and development of algorithms that enable computers to learn from data. In this article, we will delve into the concepts of machine learning, its functioning, and its significance as a vital domain of AI.The concept of 4IR gained significant attention in recent years as the world witnessed the profound impact of technology on everyday life, leading to a surge in innovations and fostering an optimistic outlook for the coexistence of humans and machines in the future. The 4IR represents the culmination of the digital revolution that has been unfolding since the mid-20th century. It is characterized by the integration of technologies that blur the boundaries between the physical, digital, and biological realms. The core idea is that technology does not replace humans, but rather complements them, becoming a powerful tool in the hands of businesses.The driving forces behind the 4IR encompass a range of digital technologies, including robotics, AI, virtual reality, blockchain, the internet of things (IoT), nanotechnology, genomics, biotechnology, cloud computing, 3D printing, big data, and more. As a result, we can anticipate the emergence of smart factories, cyber-physical systems, self-organization, novel distribution and procurement systems, innovative product and service development processes, increased adaptation to human needs, and a greater emphasis on corporate social responsibility.Furthermore, companies that can stay ahead of the curve and acquire the necessary skills in advance will have a competitive advantage by leveraging these new tools. The 4IR, fueled by AI, will transform workplaces from task-oriented characteristics to human-centered characteristics. This convergence of human and machine will bridge the gap between humanities, social sciences, and science and technology. Consequently, there will be a growing need for interdisciplinary teaching, research, and innovation. Embracing innovation and embracing change have become prerequisites for survival in this era.

The intelligence-driven future will be shaped by ongoing efforts to enhance network intelligence for operators, but this is a complex and long-term undertaking that cannot be accomplished overnight. Various proprietary solutions for AI in 5G systems have been explored, and some are already available commercially. AI can be driven by both data and knowledge, with the true potential of next-generation AI lying in knowledge inference and its applicability across diverse scenarios. However, it is crucial to establish policies and processes that address the ethical, privacy, and security implications of AI. International collaboration is essential to steer the evolution of AI in a direction that benefits humanity as a whole. At present, we find ourselves in an era where the Internet of Things (IoT) and related markets are rapidly expanding, with various forms of data being recognized as valuable assets worldwide. AI, Big Data analysis, 3D printers, robots, and other cutting-edge technologies all rely on datasets. Their widespread application in diverse business and personal domains signifies the growing influence of "data" in shaping our world. In this paper, we refer to this as the Data-based Industrial Revolution. The initial stage of the Fourth Industrial Revolution (4IR) centered around competition related to

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online data, and the upcoming second stage will involve competition focused on real-world data. This includes sectors such as manufacturing, services, banking, healthcare, and numerous others, as discussed in the relevant section of the paper.

Presently, there is a strong collaboration among smart governments, industries, and academic institutions aimed at promoting a strategy to cultivate a knowledge-intensive manufacturing industry through the utilization of AI and IoT. As we anticipate the rapid advancement of AI in the future, it is crucial to adopt a hybrid innovation strategy and ensure that practitioners in higher education possess a global perspective. Understanding the trajectory of global technological development is essential in order to formulate appropriate plans. It is important to effectively utilize innovation resources from various streams, both internally and across local, regional, and global levels. To avoid potential overlap, it is necessary to optimize connectivity among different departments through the implementation of diverse development strategies and incentive policies. Additionally, efforts should be made to accelerate the speed of technology transfer, thereby stimulating human, technological, economic, and social development. Given that AI will have a pervasive influence on all aspects of human life, companies involved in creating, utilizing, and deploying AI must not only consider how to employ AI devices but also how to effectively manage and secure the data they generate. This is particularly significant across sectors such as business, finance, military, security, healthcare, and food industries.

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