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Artificial Intelligence: getting around Moravec's paradox?

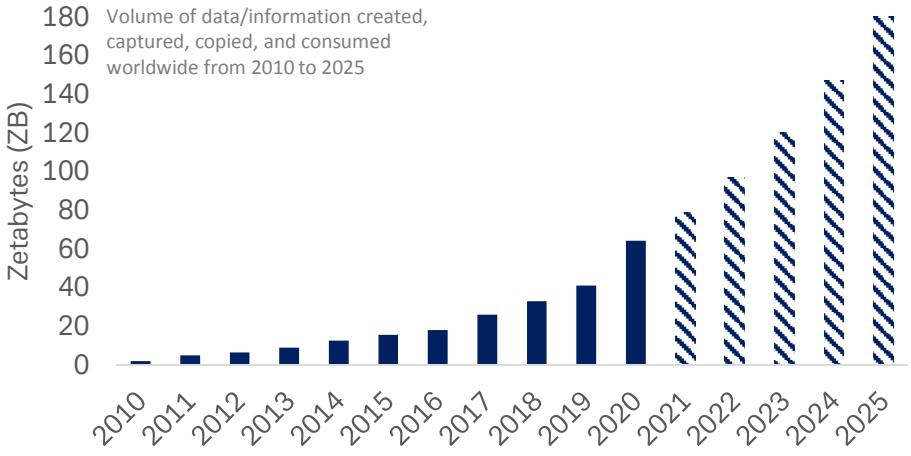
Key take-aways

- Massive strides in computational power, data storage and algorithms have finally propelled us past the limitations of Moravec's paradox.
- AI technologies are expected to have a massive economic impact, and while still in early stages, AI adoption presents unparalleled opportunities for countries to leap-frog ahead to position themselves for the future.
- Lack of a regulatory framework in AI and code of ethics for machines remains one of the greatest challenges and will be the focus in medium term.

01 Introduction

The concept of Artificial Intelligence (AI) i.e., machines exhibiting human-like cognition has been around for a few decades now. Interestingly, the main lesson of a long history of AI research has been that the hard problems were easy, and the easy problems were hard. While it was relatively easy to make computers successful at the hardest adult-level logical problems, the mental abilities of a child that we take for granted – recognizing a face, lifting a pencil, walking across a room, answering a question – were counterintuitively some of the hardest problems for a computer. This observation was known as Moravec's paradox, after the Austrian scientist, Hans Moravec. He reasoned that the oldest human skills (motor, language) are largely unconscious after billions of years of evolution while abstract thought was more recently acquired, and hence easier to reverse-engineer. This limitation meant that AI applications for the most part of history, were concentrated to very niche domains. However, it's only in the first decades of 21st century with massive strides in computation power, data generation/storage and machine learning technologies, we finally are at a pivotal point to enter into a true age of artificial intelligence.

Figure 1: ~70% of all world data has been produced only in the last 5 years



Source: International Data Corporation (IDC), Statista, Deutsche Bank AG. Data as of June 2021.

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02 What AI is, and what is not

All computer systems or machines that can continuously scan their environment, learn from it, and act in response to what they sense, as well as to human-defined objectives, constitutes AI. There are broadly three types of AI:

I. Basic AI or **Artificial Narrow Intelligence (ANI)**: limited in scope and restricted to just one functional area.

II. Advanced AI or **Artificial General Intelligence (AGI)**: is advanced and usually covers more than one field, such as power of reasoning, abstract thinking, or problem solving at par with human adults.

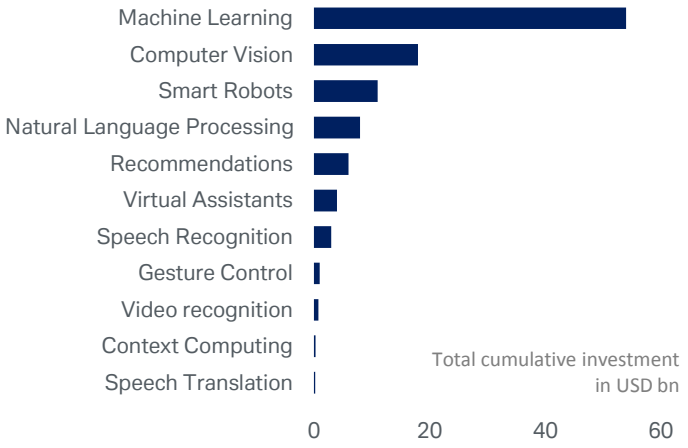
III. Autonomous AI or **Artificial Super Intelligence (ASI)**: is the final stage of intelligence expansion in which AI surpasses human intelligence across all fields and / or becomes self-aware. This stage of AI, also called 'AI singularity', is not expected to be developed for several decades.

Today, we are somewhere between the ANI and AGI mark. The leap from basic machines to an advanced stage of ANI took a long time – more than 30 years – in line with Moravec's constraint that it was easier to build AI for specific adult-level tasks that humans find complex but hard to replicate simple, sensorimotor skills that came instinctively to humans.

However, certain factors changed the equation in the 21st century. The sheer volume and diversity of data produced (Figure 1) – and more than 80% of it in unstructured format – for the first time started to comfortably surpass our ability to consume it manually. Combined with that, the massive strides in computing power reached a pivotal point and highly advanced algorithms came about. To help make sense of data in today's 'Zettabyte era', while there were many advances in AI, other disruptive technologies also developed in parallel – like the field of Big Data, and several other related domains of Data Mining, Cloud Computing, Internet of Things (IoT), and Blockchain which have gained significance. They all however greatly differ from AI in the sense that while they utilize algorithms too, they lack the ability to learn and improve like AI. It is a similar case with many digital systems that use underlying AI technologies (AI-as-a-service, AIaaS) but are not intelligent themselves.

The development of Machine Learning (ML) and Deep Learning (DL) technologies has been primarily responsible for the current inroads into applications that lie in the uncharted realm of Moravec's paradox. Structurally, while ML utilizes basic learning algorithms limited to one loop of learning, DL involves several learning loops organized like the structure of our brain. The core idea behind DL is to create a child-AI which learns and develops with experience (data). Both the technologies are well-equipped to analyze unstructured data and offer modern-day use cases such as face recognition technology (Computer Vision), smartphone assistants (Speech Recognition / Natural Language Processing), self-driving vehicles (Smart Mobility) or the personal robot that helps in chores (Smart Robots) (Figure 2). These are all still examples of advanced ANI however – a result of brute force statistics, made possible by the quantity of data fed into the models and trained on specific datasets to accomplish one task. It's only in the last few years that True AGI or human-level AI is beginning to be thought of as a real possibility but as of the writing of this report, true AGI still remains speculative.

Figure 2: Machine learning leads the way in total cumulative investments in applications

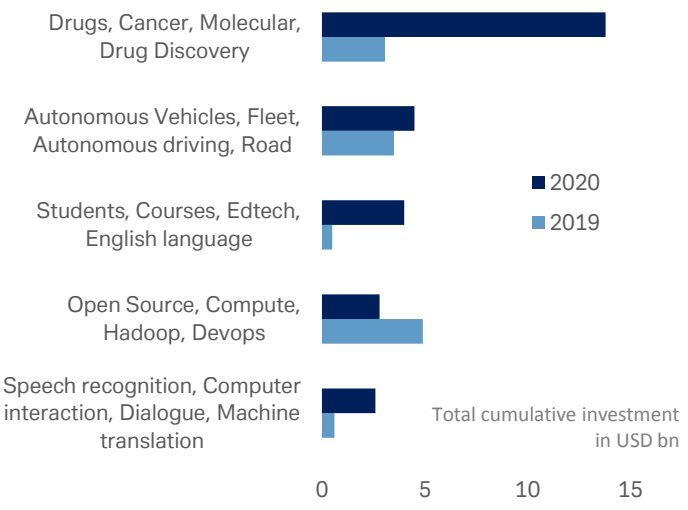


Source: Venture Scanner, Deutsche Bank AG. Data as of September 2019.

03 Status of modern AI

Unlike the last decade, AI is not a futuristic vision anymore, but rather something that is here today and being integrated and deployed into a variety of sectors. This includes fields such as finance, education, national security, health care, criminal justice, media, transportation, smart cities and more. While the scope of applications of AI is huge and evolving, they can be broadly divided into four areas as currently used by enterprises – 1) maintenance and quality control to optimize production, 2) enhancing user experience via virtual assistants, chatbots and marketing platforms, 3) research and development / predicting trends and finally 4) targeted sales and marketing. In 2020, as the pandemic raged on, the healthcare industry was overwhelmed with medical professionals at risk of being

Figure 3: Pandemic shifts focus to AI in Healthcare



Source: Stanford University, Deutsche Bank AG. Data as of 2021.

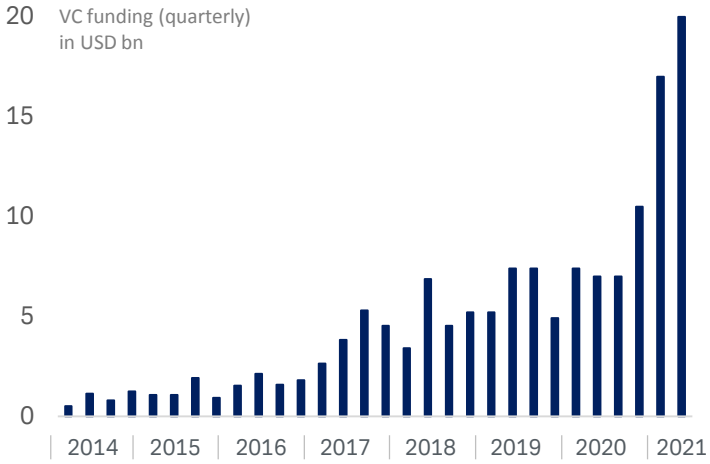
infected, overworked and fatigued. Consequently, this is also one of the leading sectors in deploying AI and beneficiary of funding (Figure 3) to efficiently diagnose patients, monitor epidemics, perform surgery and reduce drug and vaccine development cycles.

Another result of "remote working" and digitalization has been AI-powered Chatbots and virtual customer support assistants with conversational abilities. To better understand what the human says and needs, an AI-powered Chatbot uses natural language processing (NLP) and machine learning (ML) to provide a more natural, near-human-level interaction. Furthermore, such systems are increasingly being offered in the form of AI-as-a-service (AIaaS) model, aiding even the companies unwilling to build own AI systems. The rapidly evolving status quo in the investment management industry also implies AI is fast becoming an important parameter for financial and fund management companies whether it is for generating alpha, mapping relationships or driving operational efficiencies including risk management processes. As commercial uses for AI proliferate, the race to acquire AI technologies and start-ups is also intensifying – and the leading category among them has been Machine Learning (ML). As of January 2019, Venture Scanner, a technology research firm, analyzed over 2000 AI start-ups that collectively raised USD48bn in funding since 2011 – ML Startups made up half of this funding.

04 Economic impact

One of the reasons for the growing attention to AI is the tremendous opportunities for economic development that it presents. A project undertaken by PricewaterhouseCoopers (PwC) estimated that "artificial intelligence technologies could increase global GDP by USD15.7tn in 2030" – a rise of 18.5%, from current levels in 2021. A major chunk of initial impact is expected to be driven by productivity gains from businesses automating processes, with capital-intensive sectors like manufacturing and transport witnessing the bulk of disruption.

Figure 4: Venture capital funding into AI startups ramped up to record highs in the first half of 2021

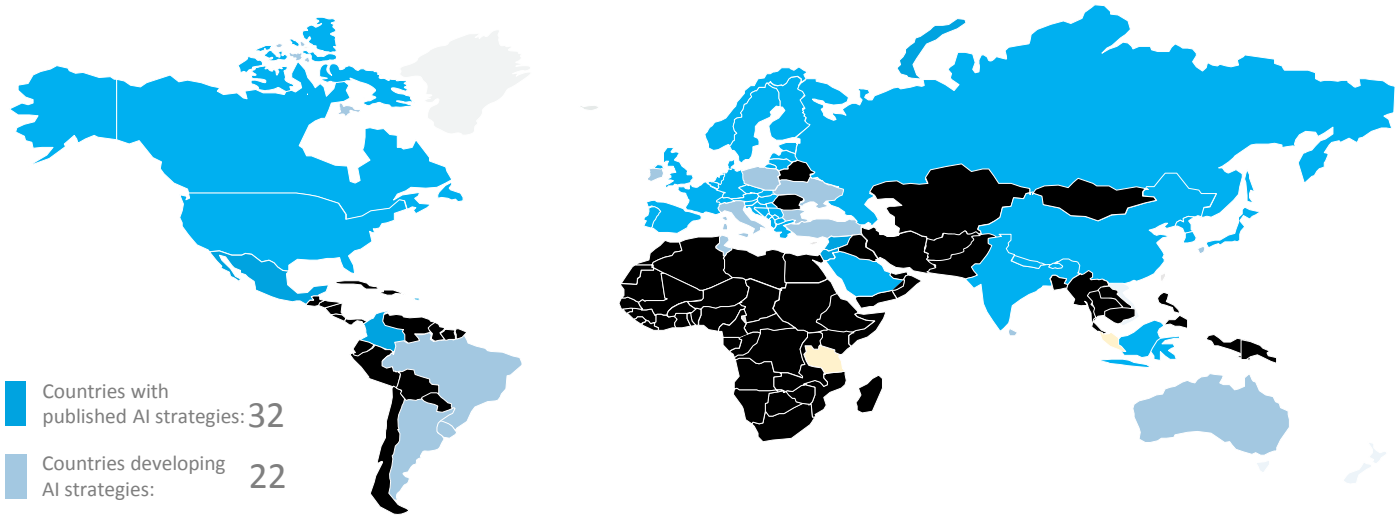


Source: CB Insights, Deutsche Bank AG. Data as of July 2021.

The next phase of GDP uplift will likely come from subsequent shifts in consumer demand and behavior and would soon have overtaken the productivity gains as consumers will mostly be attracted to higher quality and more personalized products and at the same time – have a chance to make better use of their freed-up time. There will indeed be some job displacements, especially with the adoption of 'no-human-in-the-loop' technologies but jumps in productivity, consumer demand and new technologies would also mean that new employment opportunities will arise. As per a survey by McKinsey & Company in 2020, High Tech / Telecom and Automotive industries are said to be most likely to deploy AI in business with Financial Services, Legal and Healthcare following in that order.

While some sectors and businesses are indeed more advanced than others, AI is still in early stages of development overall. Thus, from a macroeconomic and regional point of view, AI adoption presents opportunities for emerging markets to

Figure 5: Since Canada published the world's first national AI strategy in 2017, more than 30 other countries and regions have published similar documents as of December 2020.



Source: Stanford University, Deutsche Bank AG. Data as of 2021.

leapfrog more developed counterparts. Currently, China and United States lead in AI investments, Together US-based and Chinese AI start-ups represented over 80% of monetary value of VC investments in AI in 2020. China, especially, is making rapid strides in AI consistently attracting a larger share of VC investments every year. The Chinese government has also set a national goal of investing USD150bn in AI and aspires to become the global leader in this area by 2030. Led by China, Asia also comfortably leads in new industrial robot installations according to a report by International Federation of Robotics (2020).

Consequently, most of the countries today either have a national AI strategy or are in the process of developing one. However, the boost in efficiency and productivity promised by AI also presents great challenges in terms of changes to employment landscape as well as other aspects related to security, moral hazards or other kinds of undesired results, which we discuss in the next sections.

Ethics and morals in AI

By Markus Müller, Global Head CIO Office, Private Bank

In the 19th century, many societies and economies were undergoing massive structural transformations as a result of the first industrial revolution. Discussions on socioeconomic issues, including equality, justice and economic progress were all pervasive as the world stood on the brink of reorganization. Fast forward to the 21st century, a new industrial revolution – this time led by digitalization – again dawns upon us. The changes that will ensue will be among the most important yet. Ethical and moral concerns in such times specifically again come to the forefront – time has always been a trigger for new thinking and reassessment of ethical fundamentals.

It is generally accepted in the scientific community that the development of increasingly intelligent and autonomous technologies will eventually lead to these systems having to face morally problematic situations. For example, who is accountable if an AI robot-surgeon commits an error? Is it the guiding doctor? The hospital management? The software company which designed it? The regulators who approved it? Or even the patient (user) who consented to it? In addition, there are also cases like Autonomous Cars where the affected not only include the users (passengers) but also third parties like pedestrians, cyclists or children who did not consent to it. What does one do then? The main problem is that autonomous systems can't bear responsibility because they are not completely moral agents. But they can undermine efforts to ascribe responsibility. This is because it may be difficult to show that the holding agents responsible for their actions intended the consequences of actions or were at least able to foresee them, and that acted to control them. There may be situations in which a system acts "immorally" although no human agent intended this, nobody was able to foresee it, and nobody was able to control the system once it was triggered.

The role of ethics and morals in an economy is therefore to, first of all, help us define a comprehensive framework within which humans and such intelligent systems can operate together and to make sure that it is based on and reflects underlying social values and beliefs. The state must add, in a reflective and reciprocal way, general conditions and limits so that individual actors do not have to consider in every situation whether their actions meet moral and ethical requirements. However, individual ethical behavior must also prevail where there is no legal obligation.

The pandemic has already given us a first taste of why social organizations need to be maintained regardless of immediate economic calculations. There is a mutual desire of all individuals to be treated fairly and respectfully, especially on their contribution to the greater good. Individuals need to find a place in the economy (even with AI-robots working in parallel) where they can perform best, based on their individual set of capabilities augmented by relevant skills. Equality of opportunity and contributive justice are the keys to a stable socio-economic development. Again, economy and morality are in fact two sides of the same coin.

The new AI and digital technology-led world thus challenges not only our existing ideas of work, but also how we live, trade and even define ownership. Hence, it's imperative that we adopt a pre-emptive policy approach to ensure disruption is manageable and containable.

Figure 6: Leading AI issues being flagged in media (frequency of topic appearance during 2013-2018)

Source: Ouchchy L., Coin A., Dubljevic V., "AI & Society" (2020), Deutsche Bank AG. Data as of 2021.

05 Key challenges and risks

AI promises to help deliver increased consumer benefits and great business value in the time to come. But as with every nascent technology, it has its associated risks and challenges.

One of the often talked about challenges/risks is regarding the transformation of job requirements and disruption of traditional job functions as AI becomes pervasive. According to the World Economic Forum (2020), AI technologies are expected to replace more than 75 million jobs by 2022 globally. While job loss concerns have been a subject of much analysis, research and study, some experts believe the losses may not be as extreme as popularly thought. It is possible that greater AI-enabled productivity may generate jobs elsewhere with different skills – although with an unknown impact on wages. Indeed, in that sense re-skilling people and keeping them abreast with the rapidly changing technology landscape then becomes another challenge that will require a lot of investment from businesses and governments alike.

Another key challenge is regarding data privacy where we have seen several countries embark on a differentiated vision. For example, while EU has chosen to follow a strong data protection regime (GDPR), China and U.S. have a minimalist approach with greater focus on economic value. The different approaches become particularly problematic in cross-border business and data flow giving rise to many legal hurdles. Other challenges include developing a pre-emptive moral and ethical code to ensure accountability, transparency and security (discussed in the previous box) as we head towards the still-aspirational realms of AGI and potentially ASI.

However, in order to progress to these uncharted realms, there are also several developmental challenges which AI technologies are currently trying to overcome. These include enhanced man-to-machine communication – e.g., ability to interpret sarcasm, accents etc. as well as building multi-functional robots, among others, all of which can then help in truly achieving the true sense of AI.

06 Conclusion

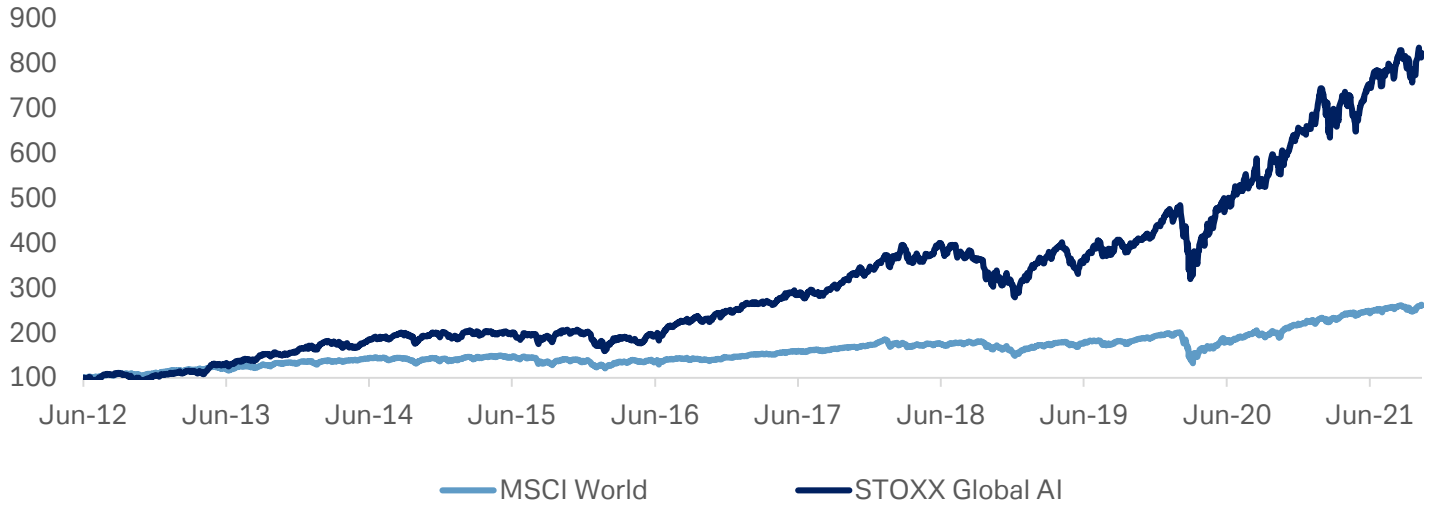
Unlike the last decade, AI is not a futuristic vision anymore, but rather something that is here today and being integrated and deployed into a variety of sectors. The leap from basic machines to an advanced stage of ANI took a long time – more than 30 years – in line with Moravec's constraint that it was easier to build AI for specific adult-level tasks that humans find complex but hard to replicate simpler skills that came instinctively to humans. In the 21st century, with massive strides in computing power, humungous volumes of data and new technologies finally helped us get around Moravec's paradox.

In terms of funding, despite the COVID-19 pandemic, 2020 saw a higher growth rate than 2019 though the number of newly funded companies continued to decrease (more private investment in AI is being channeled into fewer start-ups). Majority of the fund flows in 2020 went into healthcare sector as was the need of the hour during the pandemic. Thus, AI as a theme has shown an adaptability to changing societal needs and functions as an enabler of other technologies.

For tracking investment performance of the AI theme, we prefer the STOXX AI Global Artificial Index which is comprised of 57 global companies (October 2021) that are positively exposed to AI technologies directly or as a service. As AI develops, these companies are positioned to take advantage of the long-term trend towards automation, which is expected to have a substantial impact on their revenue in the future. The relative performance of the STOXX AI index and the MSCI World since inception is shown in Figure 7.

In the short to medium term, we expect greater emphasis on regulatory landscape in AI with emphasis also on developing a robust code of ethics for machines. At the same time, more governments are expected to come out with national AI strategies, given the tremendous opportunities for economic development as well as to counter risks that AI presents.

Figure 7: STOXX Global AI vs. MSCI World relative performance since former's inception (June 18, 2012=100)



Source: Deutsche Bank AG, Bloomberg Finance L.P. Data as of October 29, 2021.

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Glossary

AI-as-a-service (AIaaS) is the third party offering of artificial intelligence (AI) outsourcing. AI as a service allows individuals and companies to experiment with AI for various purposes without large initial investment and with lower risk.

Artificial Intelligence is the theory and development of computer systems that can learn by themselves and are able to perform tasks normally requiring human intelligence

Blockchain is a shared, immutable ledger that facilitates the process of recording transactions and tracking assets in a business network.

Cloud Computing is the practice of using a network of remote servers hosted on the internet to store, manage, and process data, rather than a local server or a personal computer.

Computer Vision is the process of pulling relevant information from an image or sets of images for advanced classification and analysis.

Data Mining is the practice of analysing large databases in order to generate new information.

Deep Learning (DL) is a type of machine learning based on artificial neural networks in which multiple layers of processing are used to extract progressively higher-level features from data.

GDP (Gross Domestic Product) is the most used measure for the size of an economy in terms of the goods and services it produces.

Gesture Control refers to the mathematical interpretation of human motions using a computing device.

Internet of Things (IoT) refers to the interconnection via the internet of computing devices embedded in everyday objects, enabling them to send and receive data.

Machine Learning (ML) is the use and development of computer systems that can learn and adapt without following explicit instructions, by using algorithms and statistical models to analyse and draw inferences from patterns in data.

Natural Language Processing (NLP) refers to the branch of artificial intelligence concerned with giving computers the ability to understand text and spoken words in much the same way human beings can.

Smart mobility is the connection of various elements of technology and mobility, a rethinking of the transportation infrastructure used in daily life and business to make transportation more efficient.

Smart Robots help in automation of repetitive tasks and common processes without the need to transform existing IT system maps.

Speech Recognition refers to a computer interpreting the words spoken by a person and converting them to a format that is understandable by a machine.

Speech Translation refers to digital tools that use advanced artificial intelligence to not only translate the words that are written or spoken, but also to translate the meaning (and sometimes sentiment) of the message.

Venture capital (VC) is a form of private equity and a type of financing that investors provide to startup companies and small businesses that are believed to have long-term growth potential.

Video recognition is the computer's ability to acquire, process, and analyze data coming from visual sources, i.e., videos.

Virtual Assistants also called AI assistant or digital assistant, is an application program that understands natural language voice commands and completes tasks for the user.

Zetabyte is a multiple of the unit byte that measures digital storage, and it is equivalent to 1,000,000,000,000,000,000,000 bytes.

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