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Sinan Küfeoğlu

Emerging Technologies

Value Creation for Sustainable Development

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2 Emerging Technologies

Abstract

This chapter presents brief descriptions and working principles of 34 emerging technologies which have market diffusion and are commercially available. Emerging technologies are the ones whose development and application areas are still expanding fast, and their technical and value potential is still largely unrealised. In alphabetical order, the emerging technologies that we list in this chapter are 3D printing, 5G, advanced materials, artificial intelligence, autonomous things, big data, biometrics, bioplastics, biotech and biomanufacturing, blockchain, carbon capture and storage, cellular agriculture, cloud computing, crowdfunding, cybersecurity, datahubs, digital twins, distributed computing, drones, edge computing, energy storage, flexible electronics and wearables, healthcare analytics, hydrogen, Internet of Behaviours, Internet of Things, natural language processing, quantum computing, recycling, robotic process automation, robotics, soilless farming, spatial computing and wireless power transfer.

Keywords

Emerging technologies · Use cases · Innovation · Sustainable development

2.1 3D Printing

3D printing, also known as additive manufacturing (AM), creates a three-dimensional product of any shape from a three-dimensional model or other electronic data sources by layering material under computer control (Dongkeon et al. 2006). In additive manufacturing, objects are built from the bottom up in layers. The layers are created in slicing software from a three-dimensional computational model of the object to be printed. These computational models are typically developed in computer-aided design (CAD) software and exported as .stl or .obj files for 3D printing. The description of the 3D printing process is shown in Fig. 2.1.

Like many other contemporary technologies, 3D printing has both positive and negative consequences. 3D printing is a widely accessible technology that allows consumers to create products in their own homes, using their own devices while also removing logistical and energy-related responsibilities from manufacturers. However, individual use of 3D printing technology may lead to unemployment among workers in the sub-production stages of manufacturing. Despite this, 3D printing technology offers overwhelming possibilities for innovation and efficient manufacturing.

3D printing technology has evolved since the first 3D printer was established in 1984, and

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Fig. 2.1 Process of 3D printing. (Campbell et al. 2011)

printers have gotten more functional as their price points have decreased. Rapid prototyping is used in a variety of industries, including research, engineering, the medical industry, the military, construction, architecture, fashion, education and the computer industry, among many others. The plastic extrusion technology most widely associated with the term "3D printing" was invented by the name "fused deposition modelling" (FDM) in 1990. The sale of 3D printing machines has increased significantly in the twenty-first century, and their cost has steadily decreased. By the early 2010s, 3D printing and additive manufacturing had evolved into alternate umbrella terms for AM technologies, one being used in popular vernacular by consumer-maker communities and the media and the other one being used officially by industrial AM end-use part producers, AM machine manufacturers and global technical standards organizations.

There are several 3D printing technologies, including stereolithography (SLA), digital light processing (DLP), fused deposition modelling (FDM) and selective laser sintering (SLS). However, the most commonly used techniques are FDM and SLA (Kamran and Saxena 2016). Scott Crump developed FDM in the late 1980s. Its wide use is due to its ease of manufacturing, relatively low cost and variety of applications. The FDM process has been applied in many areas such as biomedical, aerospace, automobile, pharmaceutical, textile and energy fields (Singh et al. 2020). FDM uses a stock material fed into a liquefier to shape the material in a liquid form easily. The material is heated to its melting temperature through various temperature treatment methods within the liquefier.

The melted material is then pushed through a nozzle to be extruded onto a Cartesian space (Campbell et al. 2011). While some printers allow the nozzle to move around in the Cartesian space, other printers build layers by moving the print bed under a stationary nozzle. The print bed spans the x and y axes, and the layers of the object which are to be printed are added towards the z-axis. Other 3D manufacturing processes use fundamentally different methods to create the different layers which are needed to give form to the final object. One such process is stereolithography, where the object is "printed" by hardening layers in a pool of photosensitive polymer using an ultraviolet laser (Campbell et al. 2011). In this method, the energy of the laser is transferred to certain regions of the liquid polymer to harden it. When all the desired regions are hardened, the printed object can be taken out of the pool of polymer. A type of stereolithography is DLP invented by Larry Hornbeck in 1987. The difference between SLA and DLP is that DLP uses UV light to harden the shape of the object at once rather than hardening different selective sections of the resin over time. Another method called selective laser sintering, also developed in the late 1980s, uses lasers to melt layers of polymeric powder to obtain the final shape. The melted section hardens in time, and it can be removed from the powder once the hardening is complete (Campbell et al. 2011). Many other methods are in use or the phases of development.

3D printing simplifies the process of transforming ideas into products. The technology allows rapid and accurate production from various materials. 3D printing also streamlines the prototyping process by providing faster production, allowing businesses to stay one step ahead of the competition. The technology uses a simple interface, allowing more equitable and widespread use. 3D printing also helps product developers to produce low-cost prototypes early in the development process, resulting in better goods and fewer dead-ends. Materials science as a field is affected largely by the 3D printing applications, as the number of materials created by 3D printing has risen considerably in recent years. The possibility of 3D printing various materials has also allowed the technology to be used in different fields. Metals, polymers, ceramics, composites and smart materials have all been successfully used in 3D printing applications with varying costs. Different materials require customisations of the 3D printers due to different material properties such as melting temperature (Shahrubudin et al. 2019). An innovative material used in 3D printing applications is smart materials, which sense variations in their external environment and provide an effective reaction to fluctuations by modifying their material characteristics or geometries. In particular, energy connection or conversion between different physical fields, such as thermal energy conversion into mechanical work, is shown as a product of smart materials. Due to the potential of smart materials, 3D-printed components of such materials might change over time in a specified way. This leads to a new phenomenon known as 4D printing. 4D printing innovations are primarily accessible by recent progress that has been achieved in multi-material printing. 3D printing of multi-smart materials or a mix of smart materials and conventional materials requires understanding the design and manufacturing processes (Khoo et al. 2015).

Benefits of 3D Printing:

- AM dramatically shortens the production period and process and provides great flexibility for the continuously changing market demand.
- Production run size can be maintained at low levels on a unit basis while manufacturing costs are not considered.
- AM reduces assembly mistakes and related expenses because pre-assembled components can be obtained through one subsequent operation, which is the quality control inspection.
- Tools are not included in the additive production process. It provides flexibility for the market adaptation and reduction or even elimination of related expenses such as toolmaking, stoppages due to referred changes, inspection and maintenance.
- Different production processes can be used in hybrid production with AM. In this situation, it can provide a combination of additive production methods with traditional methods to make advantages offered by both.
- Optimum usage of materials can be provided, and it is possible to recycle any waste material through AM (Jiménez et al. 2019).

Studies attempt to predict the impacts of 3D printing on manufacturing, supply chains, business models, competition and intellectual property. A study by Jiang et al. makes economic and societal predictions for 2030 (2017). The study results predict a trend of decentralisation in supply chains across many fields since AM will allow cheaper and more accessible localised production capabilities. This is expected to decrease the environmental impact of manufacturing due to reduced transportation emissions. The study also predicts that more than 25% of applicable, final products will be sold digitally as files to be 3D printed instead of physical products. A distinction is made between complex and less complex parts where complex parts are made centrally in specialised manufacturing locations, and fewer complex parts are distributed digitally and produced locally (Jiang et al. 2017). The study makes additional predictions about consumer markets and business models changes by 2030. Businesses' competitive advantage will no longer depend on the efficiency of their production operations but their network of users and creators. Companies will seek employees with skills related to AM, and many jobs will be replaced in the manufacturing industry. This change is reportedly due to the expectation that more than 10% of all gains from manufactured products will be from 3D-printed products by 2030. These products are predicted to be made up of many materials and electronics since enhanced AM methods will allow for such products to be 3D printed at lower costs. The affordability of 3D printers will also induce a significant increase in 3D printer ownership of individuals, especially in industrialised countries. Thus, websites that feature 3D designs will gain more popularity and will allow designs to be sold or downloaded as open-source projects. This is expected to make it harder to detect violations of intellectual property

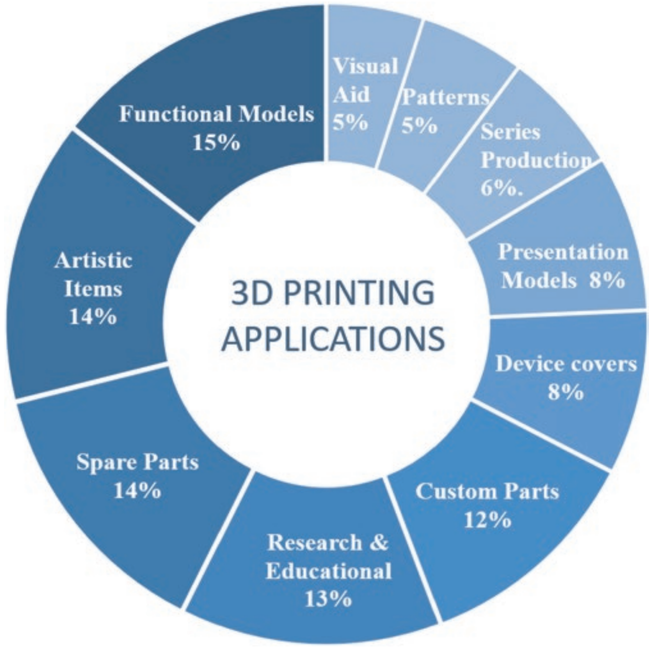


Fig. 2.2 3D Printing applications. (Mpofu et al. 2014, p. 2149)

rights (Jiang et al. 2017). It is expected that 3D printing will become more affordable, refined, purposeful and widespread in the future. The words "create it" may soon become as ubiquitous as "print it". Examples include raw commodities, satellite networks, machinery, ships and factories. When the cost of manufacturing is reduced, as it is with 3D printers, to the point that virtually anybody can purchase the "means of production", everyone will say "make it." So, the future of 3D printing technology is promising. As the applications of this technology, shown in Fig. 2.2, surge in various areas while potential future applications arise. It is expected that the 3D printing manufacturing industry will grow by 18% each year and reach 8.4 billion dollars by 2025. Especially in the automobile and aerospace industries, the usage of 3D-printed parts will increase significantly in the upcoming years (Mpofu et al. 2014).

2.2 5G

5G is a contemporary technology that offers new interfaces to all end-user devices and network components. The quest for 5G stems from the rapidly developing desire to build a highly connected and globalised world in which information and data are easily and equitably accessible to everyone around the globe. Technologies that enhance access to information and data have gone through significant improvements, with new technologies constantly developing to address the shortcomings of previous iterations. 5G is expected to address the shortcomings of 4G technology and improve upon the promises of 4G. 5G technology promises higher capacity and data rate, lower latency, larger device connectivity, lower costs and more consistent quality compared to 4G (Gupta and Jha 2015). 5G can simultaneously connect more wireless technology users with smarter, faster predecessors. 5G technology allows for network connections using Internet technology that is specified to power, battery life, size and cost in the Internet of Things (IoT) applications. 5G technology provides for a revised technological solution in terms of tonnes of wireless technologies, and it opens up new possibilities for mobile connectivity that go well beyond what is now possible, allowing new applications to be utilised in a variety of different situations (Painuly et al. 2020).

From 1G to 5G, communication technology has evolved over time. Mobile connectivity technology began in 1979 with the first generation of mobile networks, also known as 1G. 1G was a fully analogue technology. Analogue technology and frequency division multiple access (FDMA) were used in 1G, as well as Nordic mobile systems (NMT) and advanced mobile phone system (AMPS) switching. The average speed of a 1G connection was 2.4Kbps. 2G was introduced in 1991 with more services and features, including enhanced coverage and capacity and superior voice quality to 1G. The speed of the 2G network was enhanced to 64 kbps, and the first digital protocols, such as code division multiple access (CDMA), time division multiple access (TDMA) and global system of mobile (GSM), were used. 2G technology was used for voice and data packet switching. When 3G was introduced in 2003, it represented a new mobile technology and services age. Using 3G technology, the speed was upgraded to 2000 kbps, and the first mobile broadband service was launched. A new age of mobile capabilities began with the rapid growth of smartphone Internet services after introducing 3G technology. Digital voice and web data are used separately in 3G, email and SMS. 4G was introduced in 2011 and is currently in use alongside 2G and 3G. 4G speed can reach 100,000 kbps. High-speed Internet and the next generation of transportation networks are required to meet this massive demand (Saqlain 2018). By the early 2000s, developers had realised that even the most advanced 4G networks would not be able to handle the demand. An academic team has begun work on 5G since 4G has a 40–60 ms latency, which is too high for real-time responses. NASA aided in developing the Machine-to-Machine Intelligence (M2Mi) Corp, which is tasked with developing M2M and IoT like the 5G infrastructure required to encourage it in 2008. In the same year, South Korea established a 5G Research and Development program, while New York University established the 5G-focused NYU WIRELESS in 2012 (ReinhardtHaverans 2021). Historical development of the 5G is represented in Fig. 2.3.

Like existing networks, 5G transmits encoded data between hotspots using a cell system that divides the territory into sectors and employs radio waves to do so. The spine of the network must be connected to each cell, either wirelessly or through a landline. With two different frequency bands below and above 6 GHz, 5G uses higher frequencies than 4G (Pisarov and Mester 2020). 5G's improved connection was expected to revolutionise everything from finance to healthcare. 5G opens the door to life-saving technologies like remote operations, education, medicine and more. Additionally, 5G technology creates opportunities for new capabilities and enterprises. Despite the power of 4G wireless network technology, fast speed, rapid response, high reliability and power efficiency, mobile services are not enough to sustain growing demand. Thus, these qualities have become important criteria for 5G services (Yu et al. 2017).

The 5G technology consists of three main types, which are enhanced mobile broadband (eMBB), ultra-reliable low-latency communication (URLLC) and massive machine-type communications (mMTC). eMBB enables improved customer experience in cell broadband. It requires high data rates across a large coverage region. URLLC's primary applications include industrial automation, automated driving and virtual surgery. Lastly, mMTC provides support for a variety of devices, such as remote controllers, actuators and system tracking within a small area (Noohani and Magsi 2020).

5G technology can also be divided into five main categories. As shown in Fig. 2.4, these categories include immersive 5G services, such as massive contents streaming and virtual reality/augmented reality; intelligent 5G services, such as crowded area services and user-centric computing; omnipresent 5G services, including Internet of Things; autonomous 5G services, including drones, robots and smart transportation; and public 5G services, such as emergency services, private security, disaster monitoring and public safety (Yu et al. 2017). Moreover, Fig. 2.5 represents the applications of 5G.

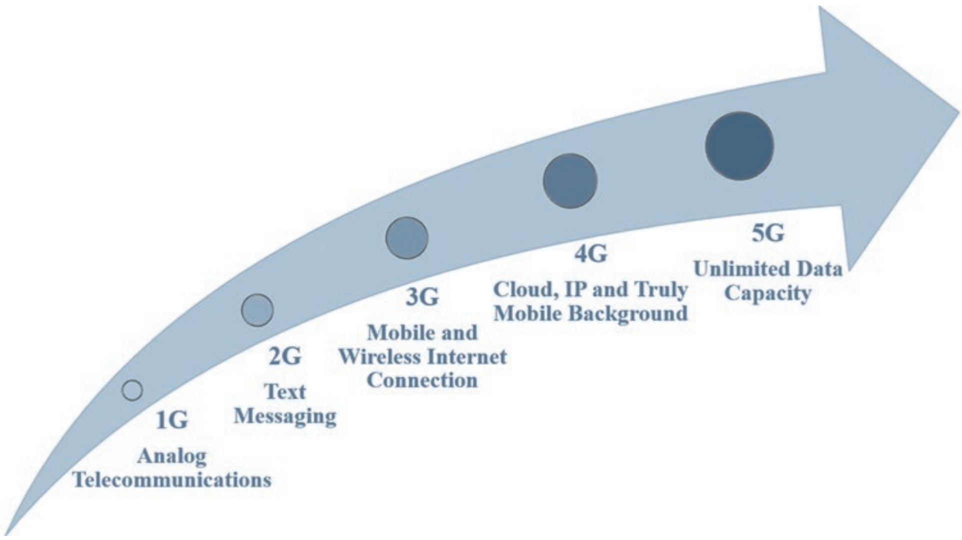


Fig. 2.3 Historical development of network technology. (Pisarov and Mester 2020)

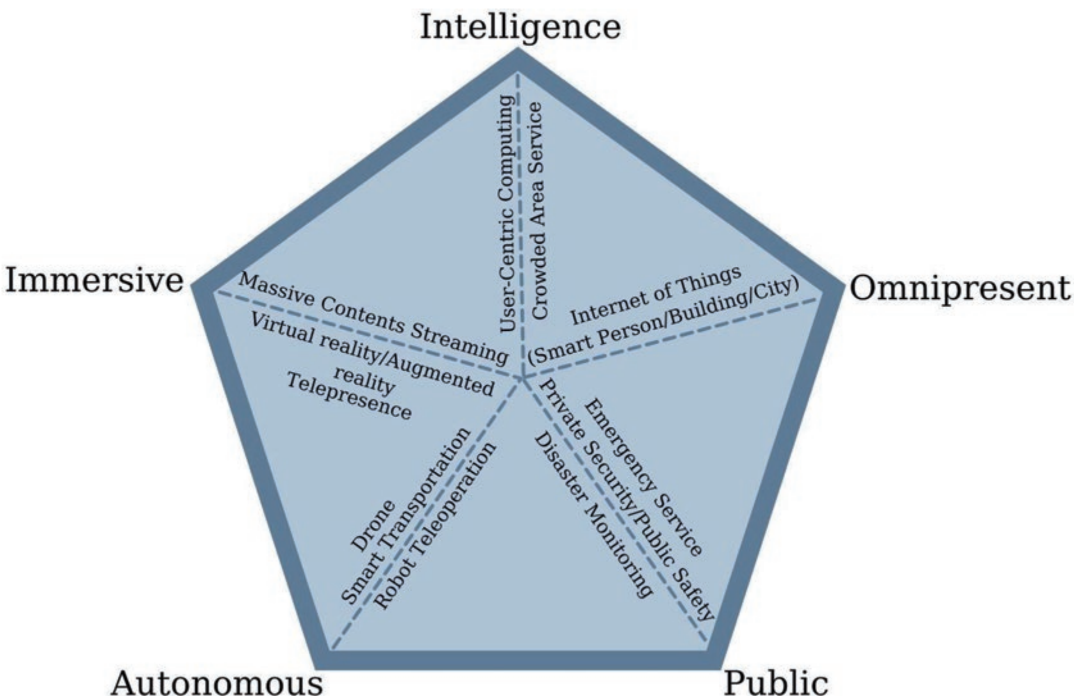


Fig. 2.4 Types of 5G technology. (Yu et al. 2017)

The widespread application of 5G is seen by many as inevitable given IoT requirements. Devices will require 5G capabilities to maintain continuous wireless connection and improve their speed and security. 5G offers significantly faster data rates compared to 4G networks. Furthermore, 5G has ultra-low latency (latency refers to the amount of time it takes for one device to deliver a data packet to another device). The latency rate in 4G is approximately 50 ms,

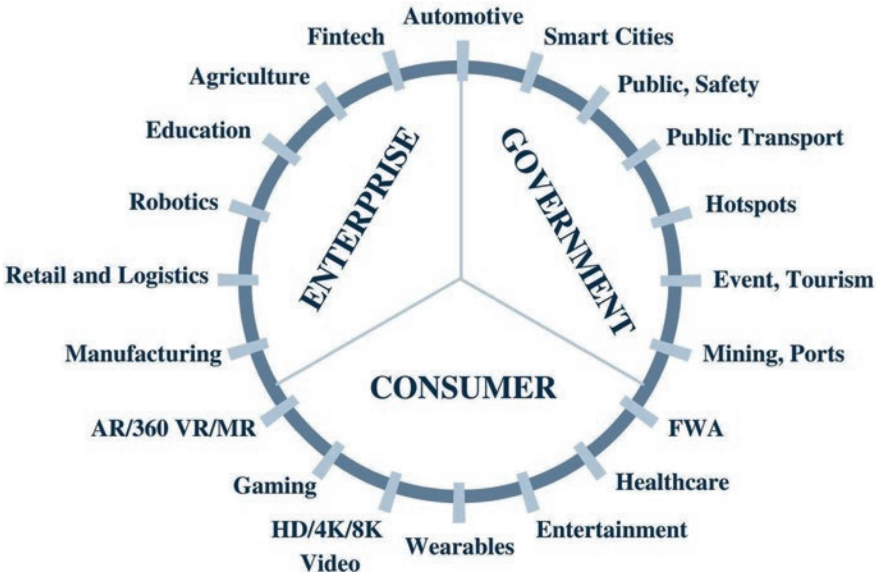


Fig. 2.5 Applications of 5G technology. (Juniper Networks 2021)

while in 5G, it will be under one millisecond. This is a critical rate for industrial usage and self-driving automobiles. 5G uses significantly less energy than previous technologies. Lower energy use facilitates the construction of battery-free IoT nodes, allowing IoT to operate as battery-free and maintenance-free endpoints.

Moreover, 5G consumes nearly five times less energy while being five times more cost-effective (Painuly et al. 2020). Also, 5G will allow a more connected world. Over the next 10 years, IoT is anticipated to develop tremendously, necessitating a network capable of supporting billions of connected objects. The capacity and bandwidth of 5G will be tailored to the user's demands (Lopa and Vora 2015). The vast majority of household devices in use, from routers to televisions, are powered by a single chip. With the advent of 2G and 3G technology, the world changed dramatically, and after the arrival of 4G technology, the world has changed even more. 5G technology is a major step forward, not only for the technology industry but for the entire globe. 5G is expected to create $12.3 trillion in world economic output and provide 22 million occupations by 2035. Moreover, it is estimated that 5G's overall contribution to the world's real gross domestic product (GDP) from 2020 to 2035 will reach the same size as India's economy (Campbell et al. 2017). As mentioned, 5G will be used mainly in three areas: eMBB, massive Internet of Things (MIoT) and mission critical services (MCS) (Campbell et al. 2017). eMBB indicates extending cellular service and increasing capacity to include more structures, such as offices, industrial areas, shopping malls and major venues, and accommodating a much larger number of devices with high data volumes (Kavanagh 2021). This will allow for more cost-effective data transmission. Secondly, the costs associated with MIoT will be significantly reduced by the energy efficiency of 5G and its ability to function in both licensed and unlicensed spectrums and the potential to supply deeper and more flexible coverage. Lastly, the adoption of 5G will fulfil the application's high reliability and ultra-low latency connectivity needs. Thus, this technology will be frequently used in the operation of complex systems to eliminate the risk of failure. When all of 5G's components are fully deployed and functioning, no wire or cable will be required to supply communications. 5G has the potential to be the ultimate answer to the old "last mile" challenge of delivering a comprehensive digital connection from the carrier network's edge to the consumer without having to drill another hole through the wall.

2.3 Advanced Materials

The materials that developed and continue to evolve recently can be defined as advanced materials. Also, these materials show high strength, hardness and thermal, electrical and optical properties and have promising chemical properties and strength density ratios against conventional materials. Energy consumption value decreases by using advanced materials. Besides, higher performance and lower cost value can be obtained (Randall Curlee and Das 1991). The subgroups of the advanced materials can be classified as metallic materials, ceramics, polymers and composites, which are combined in terms of their nature. Besides, according to their properties and usage areas, advanced materials can be classified as biomedical, electronic, magnetic, optical materials, etc. Also, whereas advanced materials have superior properties such as thermal, electrical, mechanical and a combination of these properties, they add value to the systems in which they are used (Randall Curlee and Das 1991). Also, there are a lot of advanced materials definitions. One of them is that advanced materials have potential usage in high value-added products. The other definition implies that enhanced processes improve the cost-performance efficiency of functional materials. Besides, advanced materials positively affect economic growth, life quality and environmental issues under enhanced processes and products. All new materials or modifications of existing materials with high properties have at least one aspect that can be classified as advanced materials. Furthermore, they can have completely new features (Kennedy et al. 2019). Figure 2.6 summarises some of the major advanced materials available for industrial and commercial use.

Fig. 2.6 List of advanced materials

(i) *Advanced Ceramics*

High-performance ceramics are designated advanced ceramics. They have a crystalline structure, and refined raw materials are used for the utilisation of advanced ceramics. Advanced ceramics can be carbides, nitrides, oxides and silicides such as zirconia, silicon nitride, silicon carbide, aluminium oxide, etc. They exhibit high mechanical properties like hardness, strength, modulus, etc. Also, they have high thermal and electrical conductivity, chemical resistance and low toxicity (Ayode Otitoju et al. 2020).

(ii) *Bioengineered Materials*

Bioengineered materials are mostly used for medical purposes. They are derived from natural structures, or they can be produced synthetically with different techniques. Materials such as collagen, gelatine and fibrin can be given as examples of naturally derived materials. Synthetic materials are not bioactive, unlike natural ones, and they need to undergo several processes to become compatible with biological environments (Sedlakova et al. 2019). Bioengineered materials can also be classified as biomedical materials and biomimetic materials where biomedical materials derive from natural structures and use their properties, and biomimetic materials are synthetic materials that imitate natural processes to function (Tirrell et al. 2002).

(iii) *High-Entropy Alloys*

The high mechanical, physical and chemical properties cannot be obtained by using pure metals. Because of this situation, other metals are inserted into the metal system to be used. Conventionally, alloy systems include at least one dominant metal atom and slightly alloying elements. However, the high-entropy alloys contain equiatomic or near equiatomic at least five principal metallic elements which have approximately 5–25% atomic percentage (Gludovatz et al. 2015). High-entropy alloys (HEA) have advanced properties like superior thermal stability, corrosion and oxidation resistance, high strength, hardness and wear resistance and so on. Besides, these promising properties are situated in the system thanks to four key effects of high-entropy alloys. These effects are named core effects, and one of these effects is the high-entropy effect that gives the name to the system. In addition to this, the others can be named as the cocktail effect, sluggish diffusion and severe lattice distortion effect (Tsai et al. 2013).

(iv) *Metamaterials*

Metamaterials are artificial materials with extraordinary properties. They are considered revolutionary as they can provide unusual optical and electromagnetic features (Adams and Barbante 2015). They apply in many different fields, from mechanics to acoustics. Several disciplines currently examine them since they promise a wide range of applications (Schürch and Philippe 2021). Recent work on metamaterials concentrates on the control of changing material properties (Adams and Barbante 2015).

(v) *MXene*

The compounds consisting of transition metal and nitride, carbide or carbonitride can be designated as MXene. These materials have a 2D structure and $M_{n+1}X_nT_x$ (for n = 1 to 3) formulation. M stands for transition metals like Sc, Ti, Cr, V, Nb, Hf, Zr and the like. Besides, X refers to carbon or nitrogen atoms, and T refers to hydroxyl, oxygen or fluorine. N + 1 layers of transition metals cover the N layers of carbon or nitrogen in this structure. $Ti_3C_3T_x$ is the first synthesised MXene, and in addition to this, MXene, including more than one M element, can be in two different structures, such as solid solution and ordered structure. Whereas random dispersion of two different transition metals is obtained in the solid solution structure, the one or two layers of a transition metal are covered by the layers of other transition metals in the ordered structure (Anasori et al. 2017).

(vi) *Nanocomposite Materials*

Polymer Nanocomposites

Polymer nanocomposites include polymeric matrices and nanofiller materials as additives (Abdulkadir et al. 2016). According to the types of polymer materials, the polymer nanocomposites are also divided into thermoset and thermoplastic nanocomposites (Zaferani 2018). Besides, reinforcement materials may be organic or inorganic filler. Thanks to a variety of polymer matrices and fillers, different kinds of properties can be obtained (Dhillon and Kumar 2018). Examples of the usage areas of polymer nanocomposites are drug delivery, energy storage, information storage, magnetic and electric applications and the like (Abdulkadir et al. 2016).

Metallic Nanocomposites

The nanosized additive materials are used to manufacture metal matrix composites. The metal matrix composites are produced to obtain high mechanical properties such as high strength, ductility, toughness, dimensional stability, hardness, etc. The obtaining of the high mechanical properties depends on the homogeneous dispersion of the additive in the metal matrix. If the agglomeration takes place, the mechanical properties decrease. Furthermore, the production of the metal matrix composites is divided into two subgroups – in situ and ex situ. In an ex situ process, the additives are produced before adding the metal matrix, while the addition of the reinforcement is a part of the composite production (Ceschini et al. 2017). Besides, the production of metallic nanocomposites can be classified as liquid-state, solid-state and semi-solid-state methods, respectively (Sajjadi et al. 2011).

Ceramic Nanocomposites

The ceramic nanocomposites include glass or ceramic matrix material and different types of nano additives such as nanoparticles, nanotubes, nanoplatelets and hybrids of these materials and so on. These types of nanomaterials are added to the ceramic matrix to improve the mechanical properties of thermal shock, wear resistance, electrical and thermal conductivities and the like (Porwal and Saggar 2017). Also, there are types of ceramic composite materials that include nanocrystalline matrices. These ceramic nanocomposites are designated as nanoceramics, and the dimensions of the grain size of the matrix are smaller than 100 nm (Banerjee and Manna 2013).

(vii) *Nanocarbon Materials*

Graphene

Graphene is a single-layer 2D nanomaterial having carbon atoms in a honeycomb atomic arrangement. However, there are also two- and three-layered graphene structures. The graphene exhibits different properties than fullerenes and carbon nanotubes (Rao et al. 2009). For example, the properties of the graphene are given like promising quantum hall effect, superior young modulus, high thermal conductivity, large surface area, optical transparency and so on. There are a lot of production routes to obtain graphene as single or multi-layer. The production of graphene is classified in the two subgroups as bottom-up and top-down methods. Whereas the chemical vapour deposition, graphitisation, solvothermal and organic synthesis methods are bottom-up methods, liquid electrochemical and thermal exfoliation of graphite and liquid intercalation, reduction via chemical and photothermal ways graphene oxide are designated as a top-down method. In addition to the advantages of graphene, the graphene structures can be used as composite materials with polymers, organic and inorganic compounds, metal-organic frameworks and the like. These composite materials are utilised in distinct areas such as fuel cell and battery systems, photovoltaics, supercapacitors and sensing platforms (Huang et al. 2012).

Carbon Nanotubes (CNTs)

CNTs are cylindrical structures of graphite and can be classified into subgroups such as single-walled, double-walled and multi-walled carbon nanotubes. Whereas single-walled includes a single graphene sheet, the other two groups have more than one graphene sheet. These materials exhibit high surface area, large flexibility, low weight, high aspect ratio and the like (Mallakpour and Rashidimoghadam 2019).

Fullerene

The carbon atoms number can be 60, 70 and 80 in the structure of the fullerene. C60 has a canonical structure and exhibits icosahedral symmetry. Besides, the electronic structure of fullerenes and graphene is similar, and they can be soluble with toluene. Also, fullerene shows insulator properties like a diamond. The colours of the fullerenes are different. For example, while C60 has a violet colour, C70 has a reddish-brown. The carbon arc method is used for the production of fullerenes (Ramsden 2016).

Carbon Nanofibre

Carbon nanofibres have high mechanical properties, surface area, thermal and electrical conductivity and nanoscale diameter. These excellent properties are utilised in different application areas such as energy storage, composites as reinforcement and the chemistry industry. Also, various synthesis techniques like chemical vapour deposition, templating, drawing and electrospinning can be used to obtain these materials (Mohamed 2019). Different production routes cause a variety of morphologies; these are classified as herringbone, platelet and ribbon (Malandrino 2009).

(viii) *Piezoelectric Materials*

Piezoelectric materials produce electrical energy when the mechanical forces are applied, and a change of shape occurs when the electrical energy is given to the material. Ceramics, ceramic-polymer composites, films and crystals can be shown as subgroups of the piezoelectric materials. Most of these materials are ceramic, and the performance of the piezoceramic materials strongly depends on various properties such as elastic stiffness, thermal coefficient, dielectric constant and so on (Moskowitz 2014). The common examples of piezoelectric materials are PZT, BaTiO3, PVDF (polyvinylidene fluoride), ZnO, ZnS, GaN and so on (*Electronic Textiles* 2015). The usage of lead-free piezoelectric materials has been increasing due to environmental issues. Therefore, the investigations focus on utilisation of the lead-free piezoelectric materials instead of PZT piezoelectric materials. For example, langasite, tungsten bronze structure, materials with perovskites can be shown as an example of these types of materials (Uchino 2010).

(ix) *Semiconductors*

Semiconductors are an essential component for the electronics and energy industries. The reason for them to be important is their chemical properties. Unlike other materials that act as either a conductor or an insulator, semiconductors do not have a fixed value for conductivity. Thus, they can be manipulated by external stimuli to work as a conductor while they are insulators under natural circumstances. Also, their ability to carry electrical current by positively charged matter, called "holes", in addition to electrons, enables the production of electronic parts, such as transistors and solar cells (Neville 1995).

(x) *Shape Memory Materials*

Shape memory materials (SMMs) can return to their original shape after their shape is changed by another subject or impact (Huang et al. 2010). They are primarily used in medical applications, but R&D studies are on using these materials in industries such as aerospace and automotive (Bogue 2009).

(xi) *Superalloys*

The superalloys having surface stability and mechanical strength are materials that consist of VIIIA base elements. Thanks to these superior properties, these materials are utilised at high temperatures above 650 °C. The superalloys are divided into three subgroups depending on the base elements of superalloy, which are nickel, cobalt and iron-based alloys. Besides, powder microstructure, cast and wrought are other subdivisions of the superalloy. High mechanical properties come from precipitation hardening and solid solution strengthening mechanisms. Turbine blades and aero-engine discs are examples of usage areas of the superalloys (Liu et al. 2020).

(xii) *Superconductors*

Superconductivity can be defined with an instant decrease of electrical resistance to zero at a transition temperature named critical temperature (Tc) (Bardeen et al. 1957). The superconductors can be divided into low-temperature and high-temperature superconductors. There are different types of novel superconductors. Some examples are lithium, boron or transition metals like uranium and transfer salts' complexes. For example, C60 fullerenes are promising candidates for novel superconductors because this material has advanced properties such as high critical current and magnetic field. Magnesium diboride MgB2 is also given as another example of novel superconductors. The critical temperature of this material is 39 Kelvin, and it is thought of as a high-temperature superconductor. It also has dual-band superconductivity. The other examples of this type of advanced materials are alkali oxide fullerenes, RNi2B2C, RNi2B2C, CeMIn5 (M = Co, Rh, Ir), CePt3Si, CePt3Si, Sr2RuO4 and so on. Besides, boron-doped diamond, $Na_xCoO_2H_2O$ and CaC_6 materials can be shown as the other types of new superconductor materials (Shi et al. 2015).

(xiii) *Thin Films*

Thin films have a thickness between nanometres and micrometres, and they have different properties from their thicker equivalents. They serve as surface coatings in several fields. Biomedical, mechanical, electric and thermal industries utilise thin films as protective surface coatings (Mylvaganam et al. 2015). These advanced materials can be used in different application areas such as aerospace, energy storage, refrigeration, etc. With the increasing utilisation in new energy applications like electric vehicles and fuel cells, the advanced materials give high energy and power density and flexibility. The usage of nano-enhanced materials increases the life cycle and capacity of the components used in the energy storage devices (Liu et al. 2010). Also, nanomaterials provide mechanical and electrical advantages in the systems. Thus, it is thought that these materials will become next-generation materials (Shearer et al. 2014). New types of metallic materials such as high-entropy alloys and superalloys exhibit high promising mechanical properties such as ductility, high-temperature properties and fracture toughness (He et al. 2016; Liu et al. 2020). Thanks to these advantages, the usage of new metallic materials in the medical, turbine blades and other application areas have been increasing (Anupam et al. 2019; Ma et al. 2020).

2.4 Artificial Intelligence

Artificial intelligence (AI) is defined as a system that can collect data, learn, decide and take rational actions using appropriate methods such as machine learning, deep learning and reinforcement learning. Alan Turing put forwards the first question that led to the development of the term. In his article "Computing Machinery and Intelligence", he wondered if machines could think someday as humans do (Turing 2009). Thus, research in this field started thanks to Alan Turing and then accelerated when John McCarthy coined the term "artificial intelligence" for the first time in 1955. However, many people previously thought of the term "intelligence" as a concept that only humans can have (McCarthy 1989). So, if machines could 1 day have intelligence, according to McCarthy, then the word "artificial" intelligence is more appropriate for the description.

Nevertheless, artificial intelligence as a term should be considered a system that can think and act logically, unlike human intelligence. It is necessary to model humans as rational beings instead of emotional ones (Guo 2015). So, human thinking needs to be modelled, and this can be reduced to four steps. First, the data needs to be collected, then learned and a decision will be made as a

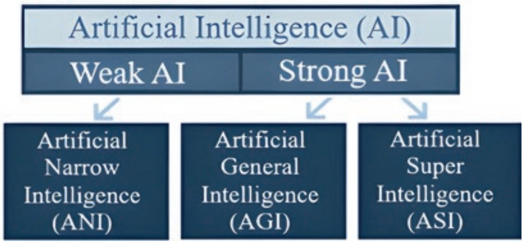


Fig. 2.7 Types of artificial intelligence

result of this learning. And in the last step, the work will be done in line with the decision made (Küfeoğlu 2021). As artificial intelligence is an emerging technology, its boundaries keep enlarging, and it continues to evolve. There are two types of artificial intelligence that human beings can produce now and hope to have in the future. Types of artificial intelligence can be seen in Fig. 2.7.

The first type is generally called "weak AI", or, namely, narrow AI or artificial narrow intelligence (ANI). This type of AI can be trained and then perform specific objectives. Unfortunately, most of the "artificial intelligence" products or services today are weak AI, and their ability is limited. Some of the good example products and services are digital assistants such as Alexa and autonomous vehicles.

The second one is called "strong AI" which consists of artificial general intelligence (AGI) and artificial super intelligence (ASI). AGI can learn from past experiences and solve problems. Also, it can plan any task. This type of artificial intelligence is in use in some buildings. However, it is still a technology that needs to be developed, and its usage area is limited because it is not especially useful.

On the other hand, ASI, also called superintelligence, is a type of artificial intelligence expected to exceed the intelligence and ability of the human brain. Also, it is the type of "artificial intelligence" that people mostly come across as an idea in movies. This type of artificial intelligence exists only theoretically, and no usage area can be given as examples from our daily lives. In addition, machine learning and deep learning come into play at this point in artificial intelligence. Artificial intelligence is achieved through machine learning (ML) and deep learning (DL). The relationship between all these can be observed in Fig. 2.8.

Machine learning is a sub-branch of AI and is based on statistics. Hence, input is given in the system, and a permanent estimate determines the output. Not only is manual coding done, but also it is aimed to develop a system that re-codes itself according to the ever-increasing data and increases its accuracy (Mohammed et al. 2016). In addition, machine learning has constantly been changing until today and has evolved with steps such as supervised learning, unsupervised learning, reinforced learning, deep learning and deep reinforced learning. As stated in Fig. 2.1, deep learning is a sub-branch of machine learning and, therefore, artificial intelligence. It is a system that simulates human speech and thinking with neural networks. It is used in many fields, such as convolutional neural networks (CNNs) and recurrent neural networks (RNNs) (Küfeoğlu 2021).

Artificial intelligence (AI) is an important technology that facilitates, accelerates and even saves human life from time to time. It was invented to be useful in daily life. For example, AI devices doing housework are easier than doing it manually, and it takes more time. AI shortens the information processing process and increases efficiency (Küfeoğlu 2021). For example, in the field of medicine, early detection of diseases has become easier. As a result of the data provided by AI, which performs morphological evaluation, it reduces the workload of healthcare professionals and facilitates the diagnosis of the disease (Mintz and Brodie 2019). Furthermore, thanks to the use of AI, the patients' medical data are stored and analysed to improve the healthcare system (Hamet and Tremblay 2017). Thus, the workflow accelerates, and patients can get the necessary treatment faster and easier.

People use many examples from daily life and do not even know that they are using AI technology. Machine translations are vastly used on the Internet and social networks, improving day by day. The computer has learned to recognise both spoken and written speech. The other example is computer games. AI is used to create a game universe that controls

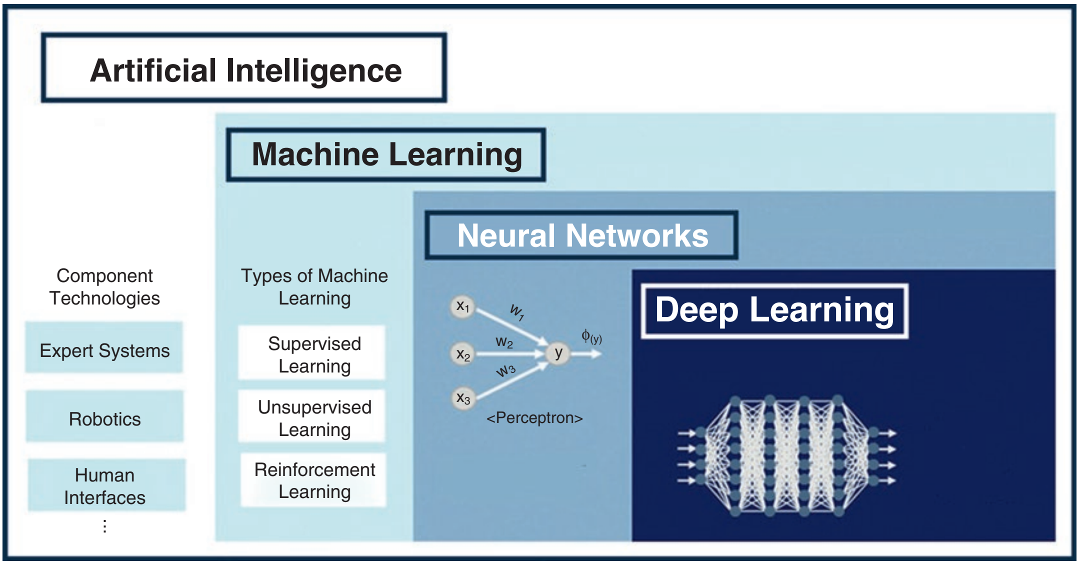


Fig. 2.8 Relationship between AI, ML and DL

bots – characters that people do not play. AI is used to create game strategies. Also, AI technologies are used to create smart houses. A special program controls everything that happens in the house – electricity, heating, ventilation and household appliances. Robot vacuums scan their surroundings to determine if they need to get started. Another example of the usage of artificial intelligence is in agriculture. It is imperative to use artificial intelligence in agriculture because it is difficult to achieve quality food in the modern world (Küfeoğlu 2021). With the use of AI, farmers can achieve a better harvest by providing their crops with more optimal conditions (Sharma 2021).

As can be seen from the examples given, nowadays, people are surrounded by AI technologies, and it is in every sphere. Thus, the main goal of these technologies is to make life easier and faster. The next thing related to the previous is that these technologies save time to spend on other things they want to do. Therefore, this is the marketing approach too. There can be an example of social media like Facebook and Instagram, where users tag their friends on the pictures, and now AI can do it automatically for them. So, the users save their time by using the media more in other ways.

There are some reasons for using AI technologies. Firstly, AI can store and process huge amounts of data. With deep learning, new data is added to the previous data, so people reach more accurate data every time artificial intelligence is used. In addition, humans are constantly affected by their emotions when making decisions. A machine with AI is not influenced by its emotions when making decisions, as it has no emotions. Therefore, the decisions taken are more objective and logical (Khanzode and Sarode 2020). As a result, AI makes the device to which it is added faster, smarter and more efficient. According to the research, artificial intelligence technology has improved data science by 9.6%, health services by 6.3%, defence systems by 5.3% and natural language processing by 5.1% (Shabbir and Anwer 2018).

If emerging technologies are considered, predicting the future is essential too. AI has been a popular, prominent research and application area recently, but the question is, will artificial intelligence evolve more in the future? AI technology can reach a wide number of applications because of the ability of machines to work with humans, collaborate digitally without any limits, make sensible decisions with the results it analyses from the data at critical points, bring various

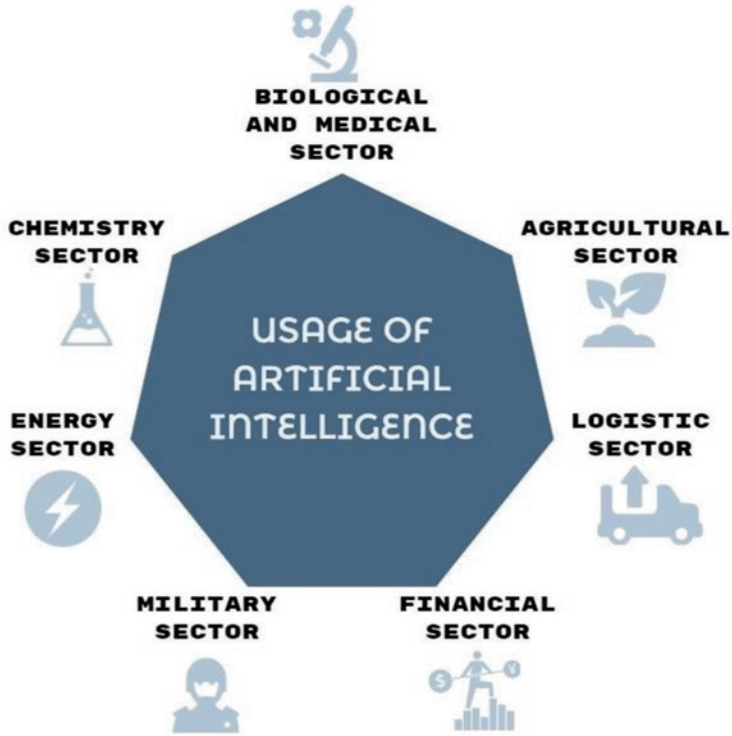


Fig. 2.9 Usage of artificial intelligence

ideas together and integrate them to produce physical or digital prototype properties. These abilities make AI a perfect technology that can continue to grow in the future. The most up-and-coming sectors that will use AI in the future are shown in Fig. 2.9.

In traditional systems, medical and biological systems do not work efficiently due to the complexity, a large amount of data and human errors. However, efficiency in new generation biological and medical systems has increased thanks to artificial intelligence algorithms. As stated by Shabbir and Anwer (2018), future applications of AI for various sectors are provided below:

- Artificial intelligence tools in the financial sector will be used to prevent market manipulation, fraud, reduction in trading costs and market volatility. It is expected that there will be systems that warn or directly intervene to solve the problem of system failures and other risks.
- AI enables the establishment and refinement of supply chains in manufacturing sectors, reliable forecasts due to data analysis, demand regulation, inventory accuracy and optimisation of programs. Therefore, the applications of AI are faster, smarter and environmentally efficient.
- The use of artificial intelligence in the agricultural sector provides smart production, storage and distribution solutions. It will also play a role in deciding on the fertilisers and chemicals to be used for the crop by instantly receiving data. Strengthening the decision-making mechanisms by showing the buying-selling balance through to its data analysis feature, by chatbot application usage preparing customer support texts to retain the customer, speeding up the support time, reducing the number of responses to the request and increasing its quality and machine learning, and this application will help people for their diet, organising their daily habits, etc. It will play a role in increasing the price-performance ratio for the consumer.
- It is expected that students will develop methods that increase the rate of study and learning

by analysing their working styles, working hours and learning styles. In addition, thanks to machine learning, analysing students' physical or psychological conditions and increasing their success rate are made possible.
- Artificial intelligence will be used to identify new drugs in large-scale genome research, providing the necessary support to find new genetic problems and efficiency. AI will help decide or prescribe drugs, whilst being aware of the patients' health problems.
- Within the field of logistics, the use of artificial intelligence will improve the making and management of delivery schedules and efficient channel vehicles.
- When people use online services or social media, AI will make interface adaptations, personal assistants and chatbots more consumer centric and user friendly. The required product quantities will be determined by the analysis specific to customers.
- AI can be used to integrate and control renewable energy sources, enable self-healing networks and harness power system flexibility, especially to encourage the use of renewable energy in developing economies.
- Potentially, military balance and future warfare will heavily be affected by the future of AI technology because of the developments in robotics and automatisation (Allen and Chan 2017). Some reconnaissance and attack missions will be planned to be done using AI-supported unmanned weapon systems that will be deployed soon. Moreover, it is expected that clandestinely designed AI systems might be used to penetrate advanced air defences. Lastly, the development and use of AI-augmented systems are expected to reduce the vulnerability of an army to cyberattacks (Johnson 2019).

2.5 Autonomous Vehicles

Autonomous vehicles are vehicles that can perform their functions with artificial intelligence algorithms defined in their content, sense their environment and operate without the need for human intervention. With the astounding growing speed of technological developments, significant improvements have been made in the development of autonomous vehicles. The automotive industry, especially, has achieved significant advances in the mechanical and electrical characteristics of vehicles since the 1920s. Autonomous vehicles have also been envisaged as the most popular objective in this respect. Various automotive firms and universities made numerous attempts to pioneer autonomous cars between 1920 and 1980. In the 1920s, a radio-controlled driverless automobile was one of the earliest demonstrations (Davidson and Spinoulas 2015). The fact that there was a lot of development in the field of science and technology in this time period was the most important factor affecting the situation of autonomous vehicles from the 1980s to nowadays. Although the dream of autonomous vehicles dates back to old times, it took the 2010s to meet the technical requirements and take realistic steps.

In the working mechanism of autonomous vehicles, many components are widely used, such as complicated artificial intelligence algorithms and devices with high processing power, sensors and actuators (Gowda et al. 2019). GPS (global positioning system), LIDAR (light detection and ranging), RADAR (radio detection and ranging) and video camera technologies are also integrated with these components (Ondruš et al. 2020). In the context of GPS, the users of vehicles, municipalities and technology-driven businesses get help in the field of transportation planning from the mapping and power of data functions of GPS (Bayyou 2019). Therefore, the inclusion of GPS inside of autonomous vehicles can increase the efficiency of vehicles by applying smart route optimisation plans and gathering information about the environment. Secondly, lidar is defined as a remote sensing technology that detects the distance between a target by making it visible with light particles and works by detecting the returning light (Ondruš et al. 2020). Radar and lidar have similar properties in terms of working principles, except for the transmission source used, such as light and what it is intended to measure. In radar, which works with the principle of signal give and take, a change in the frequency of the signal occurs during the return phase from the receiver while measuring and this change is used to determine the speed of the vehicle (Sarkan et al. 2017). Lastly, detecting randomised human factors and physical elements that cannot be identified in the system but are present in the traffic is not easy with radio waves and light without the contribution of video cameras (Yun et al. 2019). All of these technologies and technical components are the factors that developed the performance level of autonomy in the vehicles to provide users with a well-prepared and safe experience while driving. In this direction, it has been claimed that AVs permit "drivers" to free up the time customarily spent checking the roadways, empowering them to utilise their time more successfully by resting, eating, unwinding or working during the time customarily spent driving (Haboucha et al. 2017). Figure 2.10 shows how AVs work briefly.

Considering the effects that autonomous vehicles can offer when integrated into human life, it is obvious that it is a very critical technological revolution. According to Beiker and Calo, by eliminating the driver from the equation and relying on cars to manoeuvre themselves through traffic, this technology has the potential to enhance safety significantly, efficiency and mobility for humans (2010). Over the years, via the increase in connection speed with technologies such as 5G, advances in the Internet of Things and the strengthening of the interconnectivity of mobile devices, feasible and applicable solutions have emerged in autonomous technologies. These advancements have prepared the path for autonomous vehicle (AV) technology, which promises to minimise collisions, energy consumption, pollution and traffic congestion while also boosting transportation accessibility (Bagloee et al. 2016). Consequently, it can be

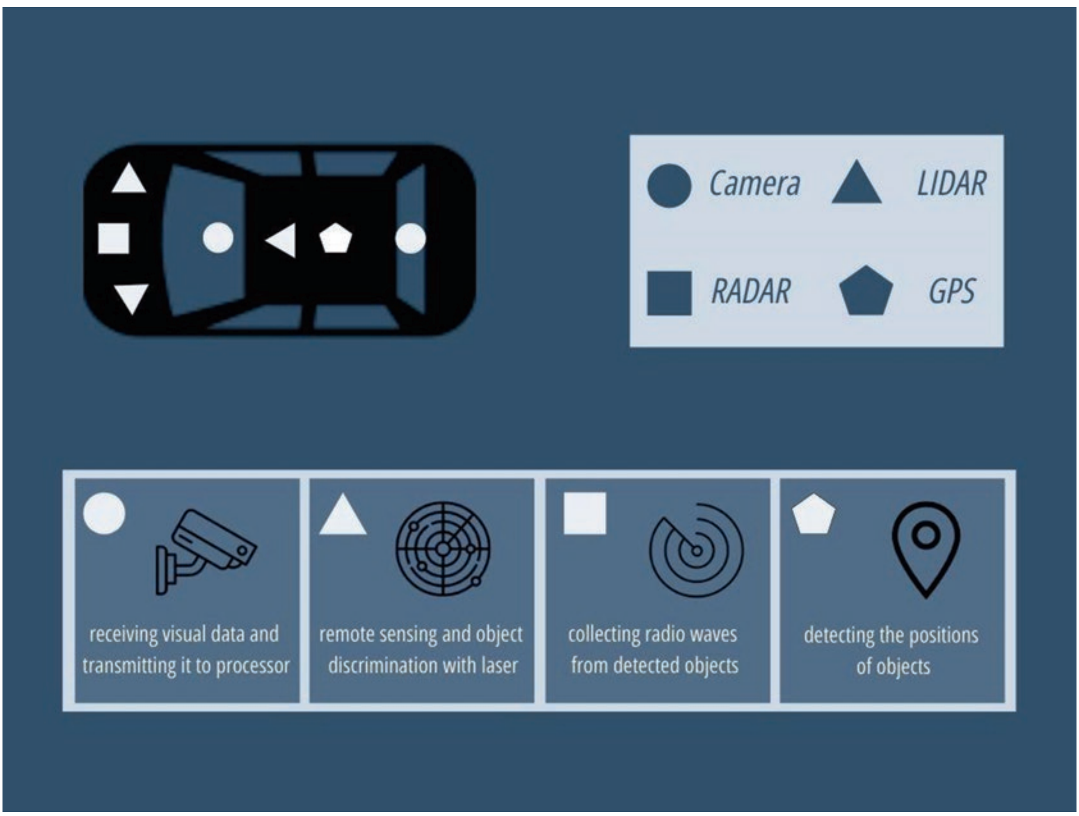


Fig. 2.10 How automated vehicles work

said that the use of autonomous technologies on vehicles, such as collective, individual and scientific research, has been helping the processes become more streamlined, adaptable and efficient for the user due to advancements in emerging technologies.

As has been stated earlier, autonomous vehicles have become significant for a large number of areas in life. Chan highlighted autonomous cars' beneficial contributions and impacts on several levels, including users, infrastructure and sustainable cities and societies (Chan 2017). Firstly, for individual users, crashes occurring with vehicles due to lack of attention can be prevented by providing a more reliable driving experience by software and hardware components included in autonomous vehicles. It would not be unfeasible to have more secure and quicker transportation in cities, which save time with the help of self-driving cars. Such junctions are expected to have an important impact on the road system of each city. The travel and waiting times will be considerably shorter (Zohdy et al. 2013). Additionally, it is thought to have an effect that can prevent 9 out of 10 accidents that occur under normal conditions (Chehri and Mouftah 2019). To sum the relationships between autonomous technology and citizens, it is possible to have a more comfortable transportation experience and fewer worries about the journeys with the integration of those vehicles into the daily life of humans.

On the other hand, in city road planning, the problems which are faced under normal circumstances can be decreased by autonomous technologies. More controllable vehicles provide a clear structure of roads, low cost of building parking lots and roads and more accessible public transportation services which can help urban planning, easier public and mobility services, an incentive for private investors on their business models. This emerging technology conserves resources for infrastructure in the city, such as parking and road development, while vehicle technology also decreases traffic and eliminates possible parking problems. The use of advanced and real-time GPS allows for a more efficient navigation experience, resulting in more accessible, dependable and adaptable routes. Besides, the sensors implanted nowadays within the autonomous vehicle are "intelligent" since they do not as it gave an information estimation but are sent with a coordinated computer program brick competent to perform, to begin with, a stage of preparing this data (Chehri and Mouftah 2019). Consequently, more efficient infrastructure due to improved vehicle control is provided by GPS and sensors.

The last promise of autonomous vehicles, sustainable cities and high-level comfort of societies can be achieved. Most governments used to develop additional roads and streets to address the rising urban environment demands. Due to a lack of public funding and physical space, the transportation network, which has a lower capacity than the population, has been overburdened, causing additional congestion, CO_2 emissions and significant disruptions to people (Dameri 2014). The previously mentioned developments regarding autonomous vehicles offer impressive solutions for sustainable cities in response to these problems. Autonomous vehicles play an important role in reducing physical and environmental noise pollution, reaching the desired level of city traffic flow, eliminating the security concerns of the city's people, speeding up regional procurement processes and reducing procurement costs (Seuwou et al. 2020). As a result, it is not impossible to reach smart, sustainable, green and information cities with the integration of AVs into urban life. Figure 2.11 summarises potential use areas of AVs.

AVs are used in many different areas of industry according to the level of automation of the vehicle. To clarify the unique function of each vehicle, defining its capabilities and complexities with their autonomy level is a must. Building a classification analysis of AVs is significant in terms of their capability to make tasks autonomously (Ilková and Ilka 2017). According to the model created by SAE International, it presents a taxonomy with precise definitions for six levels of driving automation, ranging from no driving automation (level 0) to complete driving automation (level 5), in the context of motor vehicles and their operation on routes (2018). The classifica-

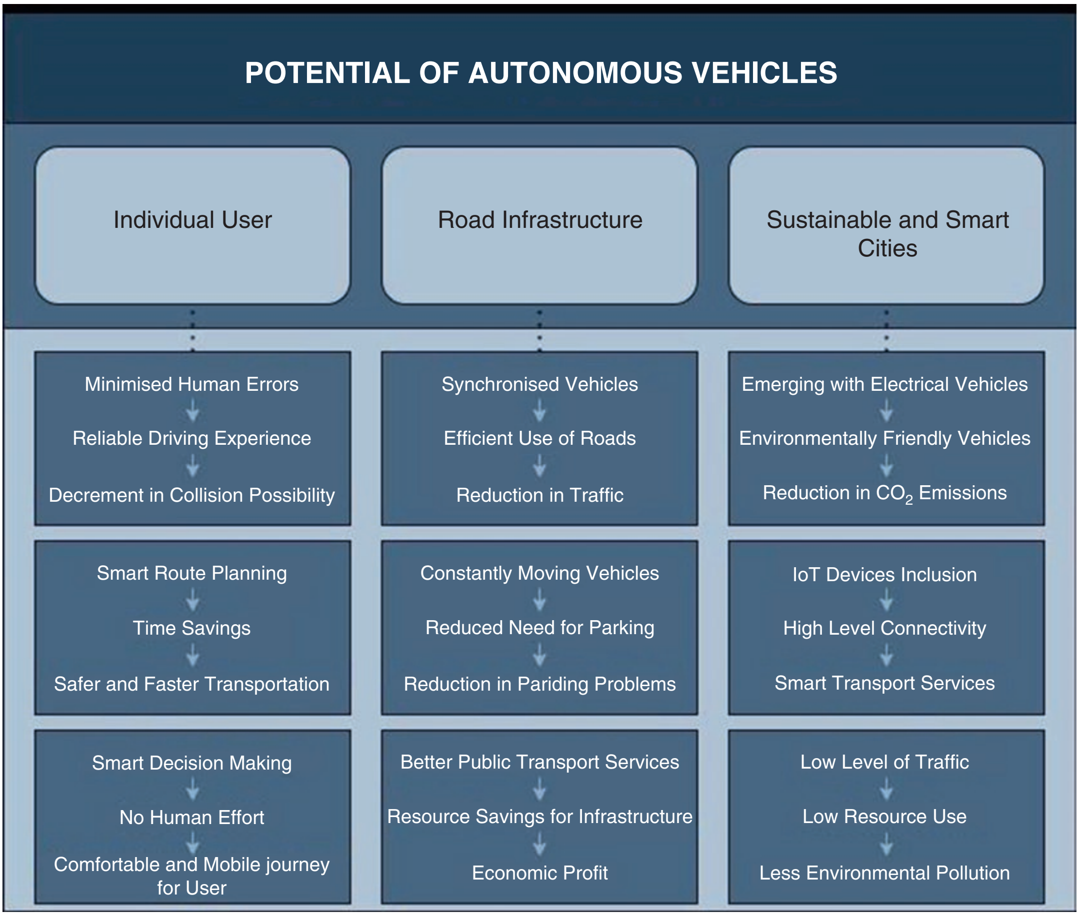


Fig. 2.11 Potential use areas of autonomous vehicles

tion system is based on how steering and braking are managed, how much human control is required when driving and whether the AV can operate without it in all scenarios (Alawadhi et al. 2020). For each level, elements represent the low processing capabilities. The difference between levels 2 and 3, where the human driver does part of the dynamic driving task and level 3 when the automated driving system performs the full dynamic driving work, is important (Ilková and Ilka 2017). Fig. 2.12 explains the automation levels in detail.

When everything is taken into consideration, it would not be an exaggeration to claim that autonomous vehicles will be very influential for the future trends of the technology world and automotive industry. When the future situation is examined, it is obvious that minor and major developments in autonomous vehicles are in interaction with each other. For user-oriented improvements, research states that the adaptation of users into autonomous vehicles will be possible with the modified after-sales mechanism, easy solutions to technical problems and flexible supply chain systems (Bertoncello and Wee 2015). Furthermore, the most used ways of transportation will be AVs by saving drivers more than half an hour per day, making quite a lot of parking space suitable for use and providing life and property safety by offering a lower error rate in driving experiences by 2050 (Bertoncello and Wee 2015). When considering the future state of autonomous vehicles, there is no significant obstacle to the increase in usage rates. Up to 15% of new automobiles produced in 2030 might be fully driverless after technology, and regulatory

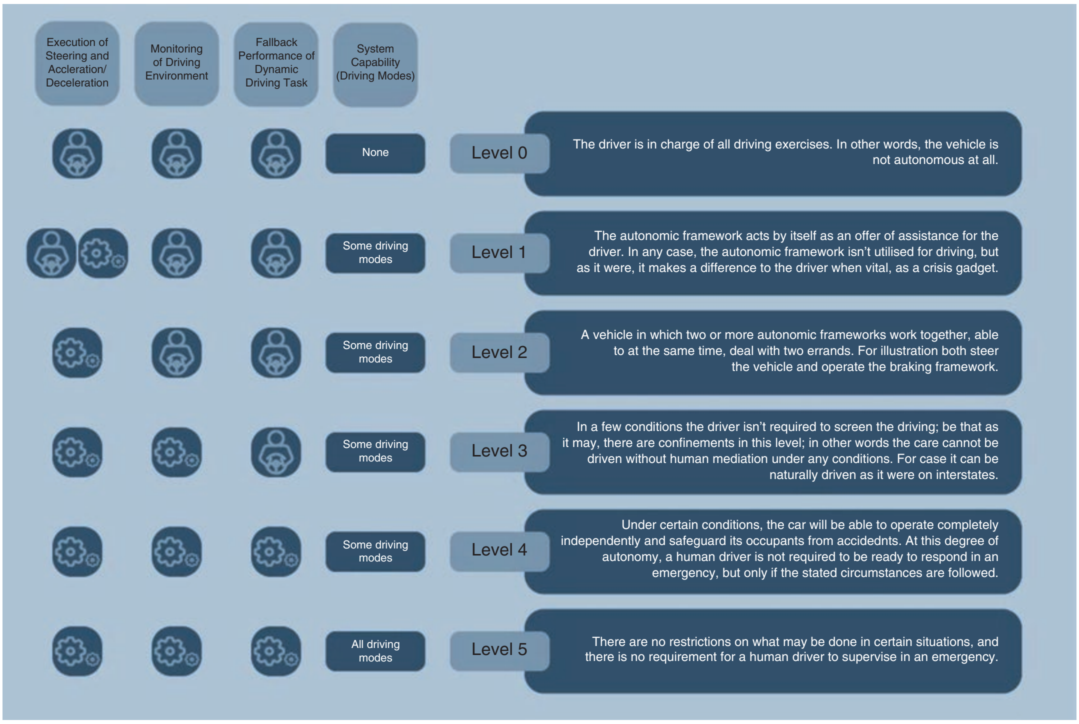


Fig. 2.12 Six levels of autonomy

concerns are overcome (Gao et al. 2016). There are serious studies of many research companies related to this subject. BCG predicted that worldwide sales would level at about 100 million per year by 2030 and that by 2035, 30% of the fleet would be electric, and 25% would be autonomous (Jones and Bishop 2020). Additionally, according to KPMG, by 2030, linked cars will account for 75% of the UK motor-park (used vehicles), with about 40% being partially automated and fewer than 10% being totally autonomous (Jones and Bishop 2020). A great deal of work falls on manufacturers and technology decision-makers to make these predictions feasible and to truly feel the impact of autonomous vehicles in the future. Considering the cumulative progress of technology, it is obvious that the development of autonomous vehicles will gain momentum with the production of prototype projects. Millions of lines of code are already embedded in the latest vehicles rolling off European manufacturing floors; the next phase of autonomous driving plainly requires both engineering acumen and digital smarts to develop, build and distribute successful automobiles (Gupta 2021).

2.6 Big Data

Big data research is at the forefront of modern business and science. It mainly includes data from online transactions, videos, images, audios, emails, logs, clickstreams, postings, social networking interactions, science data, health records, sensors, search queries, mobile phones and associated apps. These data are stored in databases, which became highly complicated to capture, store, form, distribute, manage, analyse and visualise using standard database software (Sagiroglu and Sinanc 2013). At the end of 2016, it was stated that 90% of the world's data had been produced in just 2 years, at a rate of 2.5 quintillion bytes per day. Furthermore, data is growing at an exponential pace, with estimates of more than 16 zettabytes (16 trillion GB) of useful data by 2020.

The advent of the Internet of Things, as well as the global proliferation of mobile devices – technologies, not just humans, are producing data – and the growth of social media, which has transformed everyone into a broadcaster and hence a data producer, is also adding to the quickly growing volume of data. The vast bulk of the information is no longer numerical and poorly organised. As a result, the majority of data is in the form of unstructured data, such as text, video, audio and images, which are becoming increasingly widespread (Suoniemi et al. 2020).

To put it simply, big data refers to massive volumes of information. However, size is not the only factor to consider (Oliveira et al. 2019). Although there is no singular definition for big data, there are some relevant definitions in the literature. Big data comprises structured data found in organisational databases and unstructured data created by new communication technologies (e.g. Internet of Things), such as images, videos and audio (Sestino et al. 2020). Big data also refers to a collection of enormous, complicated datasets that are too vast for traditional data processing tools and other relational database management technologies to analyse, manage and record in the timescale required. Big data also implies the diversity and velocity of data and its volume. The three Vs of big data are shown in Fig. 2.13.

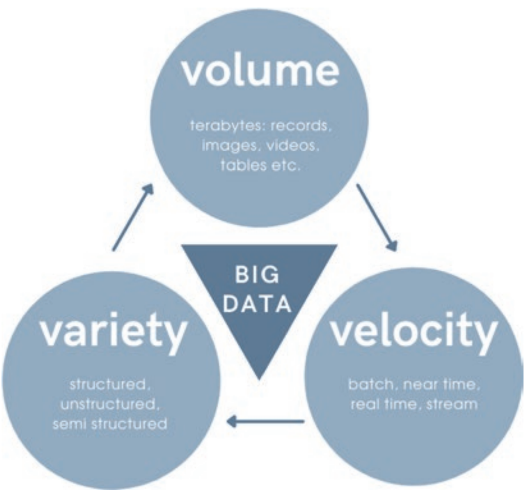


Fig. 2.13 Three Vs of big data

Volume refers to the amount of data generated from various sources. The structural variability of a dataset, which might be structured, semi-structured, or unstructured, is referred to as variety. Data that has been arranged in a way that makes it easier to analyse is known as structured data. On the other hand, unstructured data is data that is difficult to analyse and includes movies, photos and audio files. Although semi-structured data is not subject to as stringent standards as tabular data, it can be saved in XML (extensible markup language) format. Finally, velocity refers to how quickly data is produced and processed from various sources such as social media and the Internet (Oliveira et al. 2019).

According to the TDWI (transforming data with intelligence) Big Data Analytics survey, the benefits of using big data include better-targeted marketing, more direct business insights, automated decision-making, client segmentation, sales and market potential recognition, risk quantification and market trends, more lucrative investments, understanding of company transformation, better planning and forecasting (Sagiroglu and Sinanc 2013). According to current research, big data facilitates corporate decision-making through technology, systems, techniques, practices and applications related to gathering, storage, analysis, integration and deployment of large amounts of structured and unstructured data. From \$3.2 billion in 2010 to \$16.9 billion in 2015, the vendor market for big data technology has grown over 40% annually (Suoniemi et al. 2020).

Non-expert staff, cost, the difficulty of designing analytical systems, poverty of database software, scalability issues, inability to make big data usable for end-users, incompetence in reaching enough data load speed in current database software and lack of compelling business case are some of the disadvantages of big data mentioned by TDWI (Sagiroglu and Sinanc 2013). According to McKinsey Global Institute's Report, the value potential of big data is mostly unexplored and underused by businesses today (McKinsey Global Institute 2011). Three key problems that are preventing businesses from getting larger benefits from big data are (1) organisational structure and procedures; (2) strategy, leadership and talent; and (3) information technology (IT) infrastructure. Many businesses are unclear on how to integrate big data and afraid to spend on new information technology, or they just consider big data analytics to be arduous.

We live in a big data era, defined by the rapid accumulation of omnipresent information. Big data contains an infinite amount of information. It is expanding in various industries, giving a method to enhance and simplify operations (Lv et al. 2017). By becoming a necessity of our age, big data is almost everywhere. Any industry that accumulates a large amount of data, such as e-commerce, geography and transportation, research and technology, health, manufacturing and agriculture, can benefit from big data analytics. According to Andreas Weigend, professor at Stanford University and Amazon's former chief scientist, "Big Data is when your datasets become so large that you have to start innovating how to collect, store, organize, analyse and share it" (Backaitis 2012, cited in Gobble 2013). This large amount of data collected by companies and institutions is processed, providing them with an opportunity to evaluate their performance and gain insights by creating "information", which has now become a valuable resource like money (Vassakis et al. 2018). Some of the key application areas of "big data" in different sectors are shown in Fig. 2.14, and those areas can be summarised as follows (Zellner et al. 2016; Memon et al. 2017)

- Agriculture: With the latest developments in agriculture, the use of big data has increased gradually with a better understanding of its importance. With the help of the data collected from plants, it is possible to follow them in real-time, and the obstacles in front of them to grow most healthily and efficiently are greatly alleviated.
- Banking sector: Today's financial firms have been transformed into online and mobile banking. The increased usage of online and

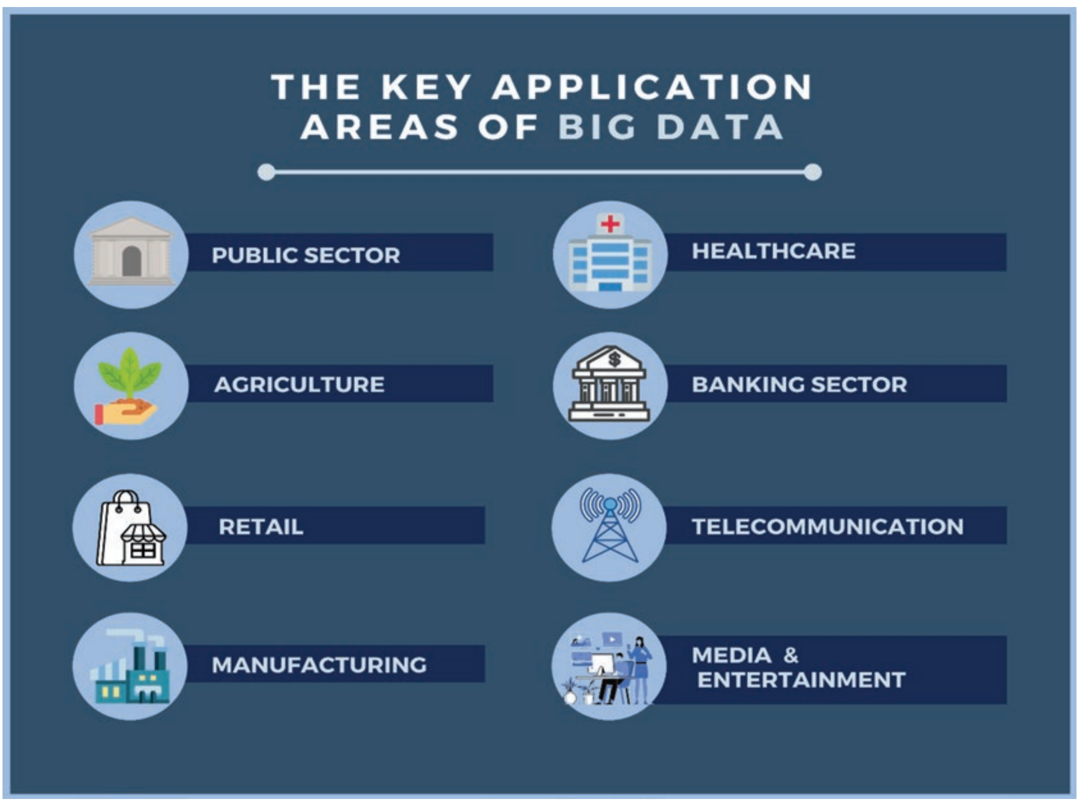


Fig. 2.14 Application areas of big data

mobile channels has resulted in fewer face-to-face contacts between consumers and banks while boosting virtual interactions and the volume of client data. Banks now have far more data about their clients than ever before regarding both volume and variety. However, only a small part of them is used to achieve successful commercial outcomes. Like most e-commerce firms, big data technology can make efficient use of consumer data, assisting in the development of customised products and services. Main application areas of big data within the banking sector include credit scoring and risk management. Automated procedures based on big data technology, such as machine learning algorithms, make loan and credit decisions in seconds. Moreover, the need for better risk monitoring, risk coverage and increased predictive capability in risk models has never been greater. Big data technology, along with hundreds of risk indicators, can help banks, asset managers and insurance companies detect possible hazards earlier, respond more quickly and make more informed choices. Big data may be tailored to an organisation's specific needs and used to improve several risk categories.

- Healthcare: Recent issues such as increasing healthcare costs and a higher need for healthcare coverage can trigger the demand for big data technology. As high-quality health services necessitate analysing large datasets, big data analytics help categorise patients into certain groups to take into consideration the differences between different patient groups. This enables healthcare providers to focus on more specific questions of concern to certain patient groups, thus significantly enhancing the quality and effectiveness of care.
- Manufacturing: With the better integration of IT technologies, the manufacturing industry has been undergoing significant changes. As the connectivity in every stage of the production process is growing, data management is highly engaged in making the existing data more manageable, standardised and integrated. The use of big data technologies plays a key role.
- Media and entertainment: Because of the impact of digitalisation, anybody can create, share and publish material. Media companies are more and more linked to their consumers and competitors. This implies that the use of big data technology to process a wide range of data sources, and if necessary, in real-time, is a significant asset that corporations are willing to invest in to make informed decisions.
- Public sector: Governments generate and collect vast quantities of data through everyday activities. The applications of big data in the public sector include the generation of data-driven insights to identify patterns and generate forecasts. Fraud and threat detection, planning of public services, supervision of private sector-based activities and prioritisation of public services are included in big data analytics in the public sector (Mckinsey Global Institute 2011; Yiu 2012 cited in Zillner et al. 2016). Moreover, improvements in effectiveness by increasing transparency through the free flow of information, creation of innovative and novel services to citizens and personalisation of services that better fit the needs of citizens can be considered as earnings of the public sector from big data (McKinsey Global Institute 2011; Ojo et al. 2015, cited in Zillner et al. 2016).
- Retail: The collection of in-store, product and customer data plays a key role in the retail sector. By enabling accurate information extraction from huge data, big data technologies provide this sector with important benefits and opportunities, such as understanding consumer behaviour and generating more context-sensitive and consumer-oriented tools.
- Telecommunication: The achievement of operational excellence for telecom players can be summarised as a combination of benefits in the management of marketing and customer relationship, service deployment and operations, which all depend on big data technologies to make sense of large amounts of internal data and data from huge numbers of users.

The increased production and availability of digital data in many areas, along with improved analytical skills due to improvements in computer sciences, has resulted in new findings utilised to improve results in many fields. In parallel with these developments, organisations are also undergoing a systemic transformation in the knowledge-based economy. Information management and big data analysis are concerned with strategies for maintaining a shared foundation of corporate knowledge, allowing different organisational units and functions to coordinate their efforts, exchange knowledge to support decisions and generate competitive advantages. In this sense, businesses effectively leverage big data to streamline processes, create efficiencies and improve services provided to customers, especially online shopping platforms such as Amazon (Madden 2012, cited in Gobble 2013). Through big data applications, corporate knowledge may spread globally and be kept in several formats, including skills and expertise in the minds of researchers and workers and organised information in databases and other big data corporate resources (de Vasconcelos and Rocha 2019), which offers opportunities for fostering innovation.

Economics, management and business data analytics are all changing in the age of big data. The emphasis on economic and management science has shifted to empirical studies and the systematic use of information technology and computer systems. The digital revolution and the global big data phenomenon are anticipated to have more impact in economic research. Researchers and corporate executives and consultants are increasingly relying on large-scale business data obtained through partnerships and corporate networking. Thanks to the Internet, corporate intranets have grown into sociability and knowledge sharing centres. There is a higher reliance on making sense of big data in today's highly connected organisational environment. This implies the need for software solutions that enable the efficient and methodical assessment of massive amounts of company data. This cause-and-effect connection leads to predictive analysis in knowledge-intensive enterprises, such as data mining methods based on machine learning and artificial intelligence. Making sense of often unstructured data may be a time-consuming effort. To successfully solve technological, skill-based and organisational difficulties, businesses must acquire a diverse assortment of big data-related IT resources (Suoniemi et al. 2020).

Today, in parallel with the increase in the number of users and devices connected to the Internet, a large amount of data has been collected in the databases of companies and technologies that will enable this data to turn into commercial value have come to the fore. With the increasing importance of data, many companies have transferred a significant amount of workload to the departments of these companies. To survive and compete, businesses must integrate industry 4.0 techniques into their activities. They must modify their management, organisation and production practices to achieve that. The best way to achieve this aim is by "reengineering": Its origins in the realm of information technology have now broadened to include the wide process of revamping key business operations to improve organisational performance. Reengineering methods give conceptual references targeted at rethinking and rebuilding corporate processes through digitalisation. The industry 4.0 revolution has stressed a collaborative link between business process digitalisation and IT since it began to develop more flexible, coordinated, group-oriented and real-time communication capabilities (Sestino et al. 2020).

Nowadays, big data is at the first stage of its evolution. Most of the businesses in different sectors still have not implemented the big data concept. However, many of them continue to work in this direction, as described before. Even in this early stage, the positive effects on the enterprises cannot be ignored. Many individuals envision big data as the planet's core nervous system, with individuals serving as its sensors. However, it is obvious that the concept of big data will lead to another revolution in the concept of business shortly, based on the competency it offers to interpret and analyse even the most variable and unrelated data (Chauhan and Sood 2021).

To put it shortly, current tools and approaches perform data processing inefficiently. The objective of all present analytical techniques and data

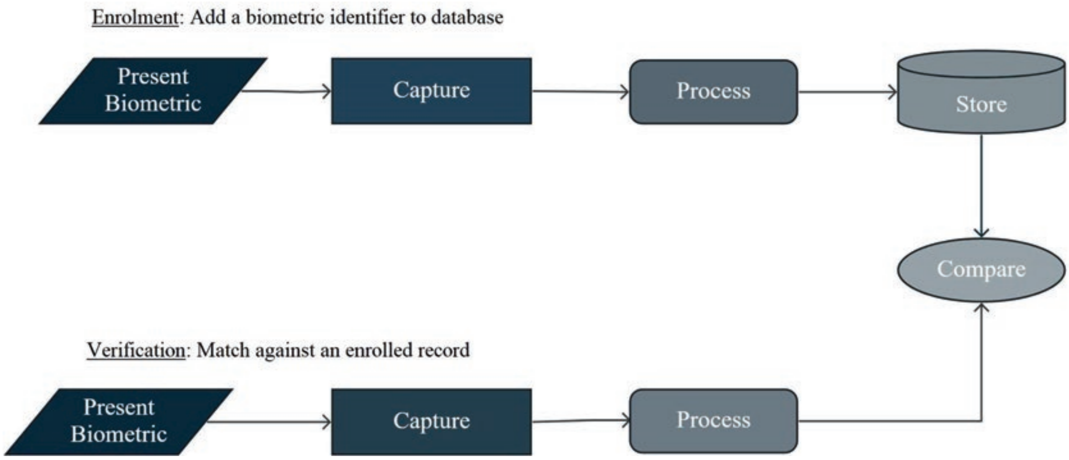


Fig. 2.15 Biometric system. (National Biometric Security Project 2008)

processing technology is to process a small amount of data. Existing technologies for large data processing reduce efficiency and generate a slew of complications. As a result, present technologies cannot entirely resolve large data challenges. Cloud computing, artificial intelligence, parallel computing, grid computing, stream computing, bio-inspired computing, quantum computing, semantic web and software-defined storage are critical research issues that need to be studied for the big data concept to be understood and applied properly (Yaqoob et al. 2016).

2.7 Biometrics

Globalisation has allowed humanity to become more interconnected, with communication between individuals increasingly mediated through technological platforms and transactions increasingly frequently conducted remotely (Fairhurst 2019). The term biometrics is derived from the Greek term *bio*, meaning "life", and *metric*, meaning "measurement" (Gillis 2020a, b). Biometrics refers to the authentication of a person's identity through chemical, physical and behavioural characteristics. Biometric technology offers a safe and convenient identification system; users do not have to remember complex passwords or carry identification documents, easily lost or stolen. Biometric identity verification systems compare an individual's live-captured unique characteristics to a biometric template stored in a database to determine their resemblance. The system authenticates the information acquired in real-time against the reference model of biometric data to verify an individual's identity. Biometric verification has a high industrial acceptance rate worldwide due to the introduction of digitalisation and computerised databases, which ensure security through fast personal identification. Figure 2.15 demonstrates the working structure of a biometric system.

Biometric technology, at its most basic level, consists of pattern recognition systems that collect biometric patterns or characteristics utilising either image acquisition devices or a combination of both. In the case of fingerprint and iris recognition systems, such as scanners or cameras, and voice and signature recognition systems, movement acquisition devices like microphones are used (National Biometric Security Project 2008). An individual must be enrolled in the system before a biometric system can be used to determine identity, as shown in Fig. 2.15. The registration process involves the collection of measurement of the individual's characteristic(s) and the storage of this data as a biometric template within the system. The template is matched to live-captured biometric data in subsequent usage. Biometric systems typically work in one of two modes after the enrolment process: biometric authentication or a one-to-many comparison. The technique of matching gathered biometric data to an individual's biometric template to confirm identification is known as biometric authentication. Rather, to identify an unknown individual using biometric identification. The individual is acknowledged if the system can match the biometric sample to a stored template within an acceptable threshold.

Biometrics have a long history, with the first examples present in the ancient Mesopotamian civilisation of Babylon. The first descriptions of biometrics are from the Babylonian civilisation around 500 BC, while the first record of a biometric identifying system dates from the 1800s. Biometrics has been around as today's technology since the 1960s. Biometric technology has continued to evolve over the years and has developed into many forms by 2021. Contemporary biometric devices collect a variety of identifying information and use it for diverse purposes across sectors. Some devices can authenticate identity without any interference or direct contact with the person whose information is being collected; this includes voice recognition, walking gait and other specific behaviours. These are considered behavioural biometrics, which detects unique distinguishing features depending on how individuals interact with their systems. Behavioural biometric systems are especially useful for cybersecurity and online fraud protection. Many behavioural biometrics applications, unlike physiological solutions, do not require an apparatus for data gathering.

Unlike behavioural biometrics, physical biometrics are based on an individual's unique and quantifiable physical characteristics. Fingerprints, retinae and DNA sequences collected from blood, saliva and other bodily fluids are key in biometric technology widely used in forensics, medicine and criminal justice cases. These biometrics require a device that links these unique properties to an existing database. The objective is to match the individual's unique characteristics to an existing record or file to identify them. Biometric travel documents are required to cross most international borders, and they provide an elevated level of security to the countries attempting to regulate who comes in and out and secure their borders. Biometric voting documents could also provide a new level of security in elections (DHS 2021). Detailed descriptions of common biometric technology are listed below, and the historical development of these two biometric types is shown in Figs. 2.16 and 2.17.

1. Fingerprint: There are two types of fingerprint identification systems, automated fingerprint identification systems (AFIS) and fingerprint recognition systems. The first one is typically used only by the provision of law. Fingerprint identification provides a unique template based on the properties of the fingerprint without preserving or even allowing for image reconstruction. The first image is obtained by scanning the finger in real-time while it is in direct touch with a reader device, checking for confirming features like temperature and pulse.
2. Hand geometry: Hand geometry is defined by the relative dimensions of fingers and joint placements. In the late 1960s, the Shearson-Hamill investment bank on Wall Street applied Indentimat, one of the earliest automated biometric systems. It utilised hand geometry for nearly two decades. Some systems are capable of taking simple two-dimensional measurements of the hand's palm. Others want to take a basic three-dimensional picture from which to extract template characteristics.
3. Face recognition: Face recognition is still in its infancy, with the majority of research and applications taking place on tiny databases. The face of the individual must be exposed to a video camera for biometric identification purposes. The possibility of tricking or confusing some systems with cosmetics is an obvious flaw in several present approaches.
4. DNA: Human DNA is a genetic structure that can be obtained in many ways, such as human hair, nails, saliva and blood. This structure is found in every cell in the human body, and it contains a lot of genetic information. Also, every person's DNA is unique, except for identical twins.

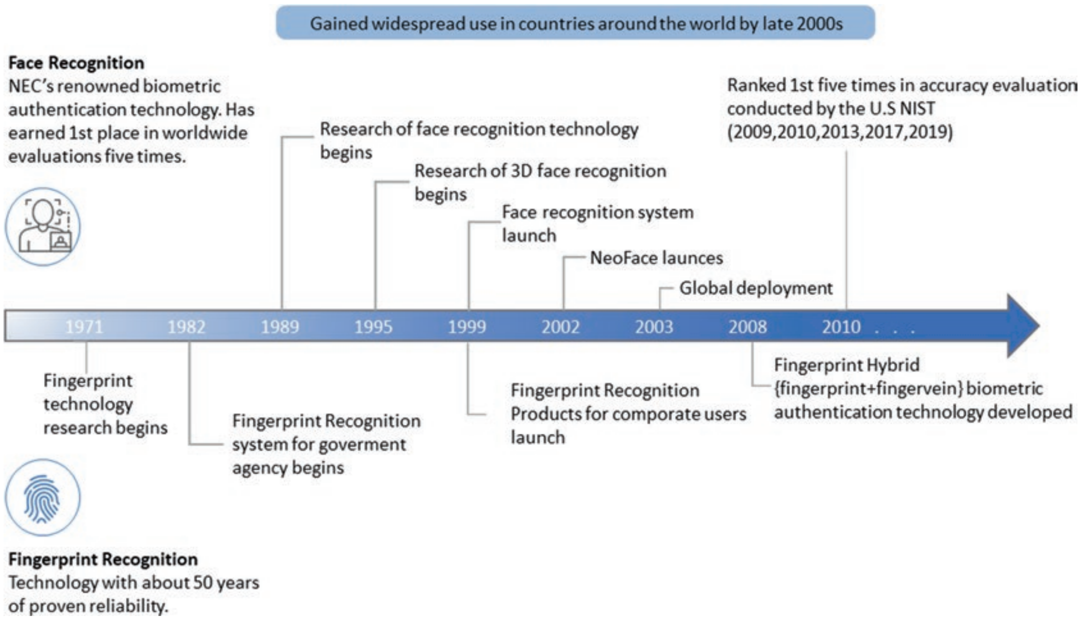


Fig. 2.16 Historical development. (RecFaces 2020)

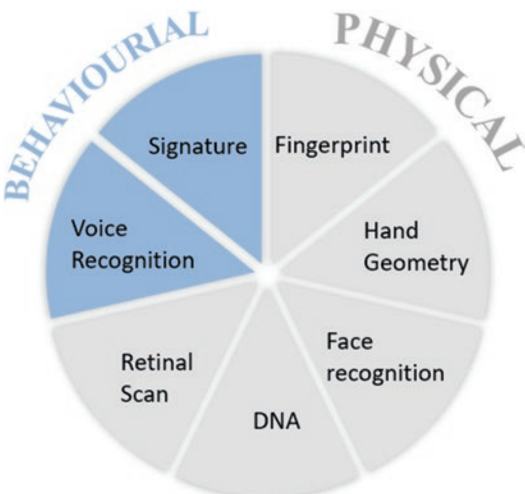


Fig. 2.17 Types of biometrics. (RecFaces 2020)

5. Retinal scan: Retinal identification is an eye signature. What allows this definition to be made is the vascular structure of the retina. A retinal scan is taken by looking at a specific target with a lens, and a retina scan is a reliable feature.
6. Voice recognition: There are two voice recognition techniques, automatic speaker verification (ASV) and the other is automatic speaker identification (ASI). The main data used in in-person identification using these methods is the person's voice. After this data is received, the system detects the voice of the person whose identity is desired to be determined by making comparisons with the templates registered in the database.
7. Signature: Identification with signature data is made with some criteria created by experts over the years. Computer systems developed for this identification method can now be as successful as an expert at detecting distinctive features in signatures. In addition, signature identification systems do not only focus on the shape of the signature but also can detect the "speed of using the pen" of the signer or the "pressure applied to the surface" while signing (Phadke 2013).

These different forms of biometrics have applications across a variety of sectors and applications which are rapidly increasing as the technology develops. As a result, biometric technology has progressed substantially in recent years, with increasing performance, faster transaction rates and lower costs (Xiao 2007). Some experts believe that new biometric technologies and applications, such as brainwave biometrics, vascular pattern recognition, body salinity identification, infrared fingertip imaging and pattern recognition, may emerge soon (Asha and Chellappan 2012). Because a biometric sensor will never capture the same data twice, comparing biometric characteristics is an inaccurate comparison; computational intelligence-based techniques may be able to solve this problem in the future. In recent years, various approaches, such as neural networks, fuzzy logic and the evolutionary algorithm, have increasingly addressed complicated biometric authentication and identification issues. Due to rising security demands, technological advancements and decreasing prices, we can expect the development of more biometric applications in the future (Xiao 2007). Although convenient and widely applicable, biometrics may also come with numerous challenges. Therefore, the following requirements should be fulfilled to execute the technology on large scales: high levels of accuracy and performance under varied operating conditions and user composition; sensor compatibility; a fast collection of biometric data in difficult operation settings; low failure-to-enrol rate, high degrees of privacy and template protection; and protecting and securing supporting information systems (Jain and Kumar 2010).

2.8 Bioplastics

Plastics constitute a huge part of people's lives because they are used everywhere. Moreover, they are employed in a variety of industrial sectors, from chemical to car. Plastics' chemical structure may be altered to create a variety of strengths and forms to get a larger molecular weight, low reactivity and long-lasting material; hence, synthetic polymers are advantageous. Bioplastics are simply plastics that are created from plants or other biological sources rather than petroleum. These can be categorised into biobased plastics, which are created at least partly from biological stuff, and biodegradable plastics, which microbes can partially or totally break down in an acceptable time scale under particular conditions.

Properties of common types of plastics are explained in Table 2.1.

The properties of these plastics are explained in Table 2.1. While they are useful, they pose a threat to the environment. Unfortunately, 34 million tonnes of plastic waste were produced per year, and 93% of the material was dumped into oceans and landfills (Mekonnen et al. 2013). Plastics dissolve in nature extremely slowly. This causes the products to pollute the environment throughout the years. Biobased plastics, which is organic material from animals or plants, is a better alternative than petroleum-based plastics. Biobased plastics can dissolve in nature faster when suitable conditions are provided. Its process depends on environmental conditions such as temperature, materials and application. Biodegradation is when microorganisms found in nature convert materials into natural substances with a chemical reaction (Kerry and Butler 2008). These are important features for plastics to prevent negative environmental impacts. In Fig. 2.18, plastics are divided into four according to these characteristics:

The shaded part in Fig. 2.18 represents bioplastics. Bioplastic is described as a plastic substance that is either biobased or biodegradable or has both qualities (European Bioplastics 2020). Bioplastics can derive from biomass such as sugar cane or cellulose; this process is called biobased (Gill 2014). Renewable biomass resources derived from natural biopolymers (e.g. carbohydrates, proteins and recovered food waste) are used to manufacture bioplastics (Brodin et al. 2017; Yamada et al. 2020). Besides the biopolymers, microalgae is a strong biomass source to produce bioplastic. *Chlorella* and *Spirulina* were the most common algae species used in manufacturing biopolymers and plastic blends. Bioplastic can be made from by-products of high-value chemical manufacturing from microalgae, as per a biorefinery approach (Onen Cinar et al. 2020).

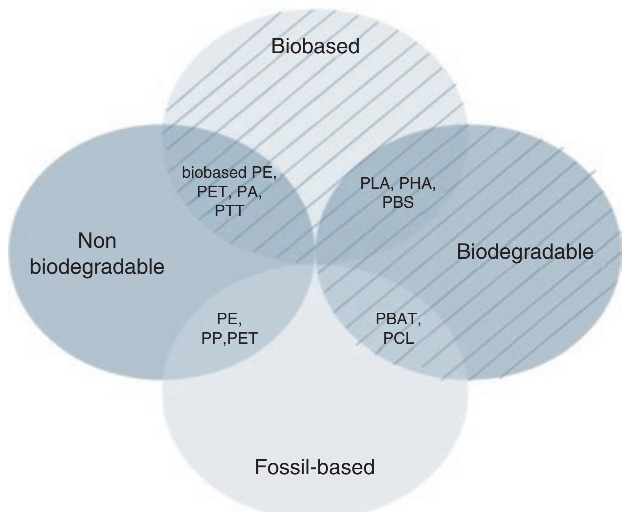
The increasing demand for plastic use day by day, and due to the degradation time of some plastics in nature being longer than 100 years

Table 2.1 Types of plastics

Plastic	Properties
PE	Polyethene has a long chain of carbon atoms. For instance, CH_2
Biobased-PE	Bio-ethylene is converted to bio-PE using a traditional catalyst-driven polymerisation process
PET	The polyester family of polymers includes polyethene terephthalate, which is a general-purpose thermoplastic polymer
PA	Polyamides are known as nylons. Such kinds of plastics are stiff; therefore, they resist bending and abrasion
PTT	Polytrimethylene terephthalate is a synthetic material. Condensation polymerisation or transesterification is the procedure used to make it
PLA	Polylactic acid is polyester made from renewable biomass, most commonly fermented plant matter
PHA	Polyhydroxyalkanoate is a kind of polyester created by bacterial fermentation in nature
PBS	Polybutylene succinate is a biodegradable plastic that dissolves into water and carbon dioxide when it interacts with microorganisms in the soil
PBAT	Polybutylene adipate terephthalate is a biodegradable polymer that decomposes due to the action of naturally occurring microorganisms
PCL	Polycaprolactone is a biodegradable polyester that has a very low glass transition temperature
PP	Polypropylene is a synthetic polymer made from natural resources

Di Bartolo et al. (2021)

Fig. 2.18 Classification of plastics. (European Bioplastics 2020)



(only an estimate due to lack of time), this emphasises the need to either reduce the use of plastics (which should be legally encouraged) or replace non-degradable plastics with plastics which are degradable and are produced in a sustainable way (Karan et al. 2019). According to 2019 data, bioplastics constitute approximately 1% of the 360 million tonnes of plastic produced annually. But as more complicated materials, applications and products emerge, the demand for bioplastics is increasing and the market is growing rapidly. The bioplastic industry has become a young and innovative sector, both economically and ecologically, in the name of a sustainable bio-economy, as it uses its existing resources more efficiently and produces lower carbon emissions (European Bioplastics 2020). Biodegradable plastics have a bright future ahead of them. The following are some of the benefits of bioplastics (Bezirhan Arikan and Ozsoy 2015):

- Carbon footprints are reduced. It should be emphasised that the carbon footprint of a bioplastic is highly reliant on the plastic's ability to permanently store the carbon that the growing plant extracts from the air. Plastic generated from a biological source sequesters CO_2 emitted by the plant's photosynthetic process. This sequestration is reversed if the resultant bioplastic degrades back to CO_2 and water. However, a permanent bioplastic that is meant to be like polyethene or other common polymers permanently retains CO_2. Even if the plastic is recycled numerous times, the CO_2 collected from the atmosphere remains retained (Chen 2014).
- Independence. Bioplastics are made from renewable resources such as maize, sugar cane, soy and other plants, as opposed to conventional plastics, which are made from petroleum (Yu and Chen 2008).
- Efficient energy usage. The manufacturing process is more energy-efficient than that of conventional polymers. Plastics are made from around 4% of the oil used each year globally. Plastics manufacturing becomes more susceptible to price changes (Chen 2014).
- Eco-safety. Additionally, bioplastic produces fewer greenhouse emissions and is contaminant-free. Yu and Chen demonstrated that bioplastics provide a considerable contribution to the objective of lowering GHG emissions, emitting just 0.49 kg CO_2 during the fabrication of 1 kg of resin. When compared to 2–3 kg CO_2 equivalents from petrochemicals, it equates to an approximately 80% reduction in global warming potential (Yu and Chen 2008).

Today, bioplastic is used extensively in four industries. Figure 2.19 summarises the use areas as follows (Bezirhan Arikan and Ozsoy 2015):

Recent increases in crude oil costs and the potential market for agricultural resources in the area of bioplastics give a push to utilise ecologically acceptable alternatives to materials generated from fossil fuel sources. Thus, bioplastics have established a new study topic for scientists by providing a viable option for global sustainable development ("Bioplastics – are they truly better for the environment?" 2018). The environmental effects caused by normal plastics, which are not biodegradable for a long time, have pushed scientists to develop materials that are produced from natural sources such as plants, bacteria and biomass and can dissolve in nature in a short time. New developments may lead to increased productivity in production and new opportunities in the field of bioplastics in the future. In addition, since microorganism biology can be applied and commercialised in different sectors such as agriculture, medicine and pharmacy, it also provides an opportunity for bioplastic production. Therefore, current guidelines for the manufacture, usage and disposal of bioplastics should be defined. Labelling regulations should be designed following the emission values of the items, the raw material used and the energy used. Recent advances in technology, global support and continuous innovation are important for promoting and commercialising bioplastics. Here, instead of competing with traditional materials, bioplastics should aim to increase their usage rates over time (Sidek et al. 2019). Bioplastics have some challenges which should be considered for future implementations:

- It is accepted that normal plastics' costs are lower than bioplastics. Nevertheless, when the production of bioplastics increases, the cost is expected to decrease (Bezirhan Arikan and Ozsoy 2015).
- If bioplastic and normal plastic are not distinguished from each other, confusion occurs in the recycling process (Bezirhan Arikan and Ozsoy 2015).
- Bioplastics are produced from renewable sources, which means that sources could be reused repeatedly (Lagaron and Lopez-Rubio 2011).
- Some terms can be misunderstood. For example, bioplastics are known as compostable. This feature confuses people's minds. They think that they can produce bioplastics from food, but the truth is that the production of

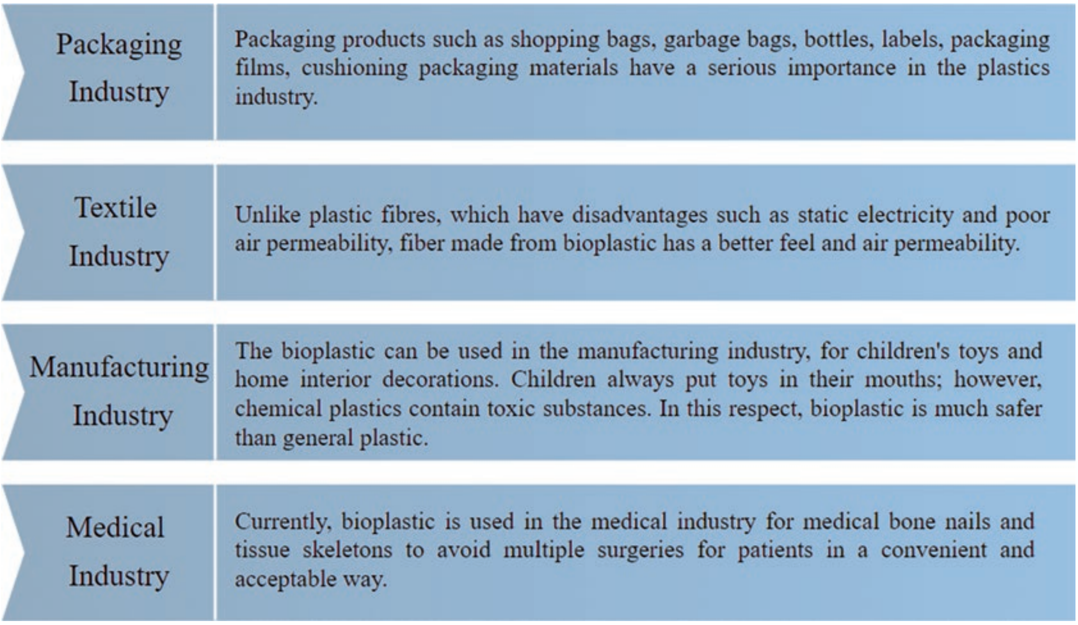


Fig. 2.19 Bioplastics industries

bioplastics is an industrial implementation (Warren 2011). Manufacturers are responsible for that misunderstanding because they try to make their products more attractive on the market (Bezirhan Arikan and Ozsoy 2015).

- Due to the lack of legislation, many countries produce bioplastics despite the absence of any law and legislation. The number of bioplastics produced is expected to increase from day to day; however, the lack of legislation makes it difficult to accurately monitor (Bezirhan Arikan and Ozsoy 2015).

A variety of assays may be performed to evaluate how bioplastics degrade. It is critical to establish worldwide standard techniques that are comparable. Regrettably, existing standards have not been equated and are mostly applied in the nations where they were developed. All details must be standardised as soon as possible. For the manufacture, use and management of bioplastic waste, a new guide and standard should be developed specifically for bioplastics. In addition, labelling laws might be modified depending on a product's raw material usage, energy consumption, manufacturing and use emissions (Bezirhan Arikan and Ozsoy 2015).

2.9 Biotechnology and Biomanufacturing

In the most general sense, biotechnology can be defined as the synthesis of modern technology and naturally existing biological processes. Biotechnology, or biotech, uses biological systems and/or living organisms to develop new technological instruments, products and machines across a wide range of fields and disciplines. There are three main branches of biotechnology: genetic engineering, protein engineering and metabolic engineering (Gavrilescu and Chisti 2005). Biomanufacturing is a type of manufacturing that uses biological systems (such as living microorganisms, resting cells, animal cells, plant cells, tissues, enzymes or in vitro synthetic – enzymatic – systems) to make commercially feasible biomolecules for use in the agricultural, food, material, energy and pharmaceutical industries (Zhang et al. 2017). Despite its connotation as some of the most advanced technology in the contemporary world, biotechnology has existed for centuries and even millennia, albeit in simpler forms than those we know today. Two often-cited examples of early biotechnology are bread bak-

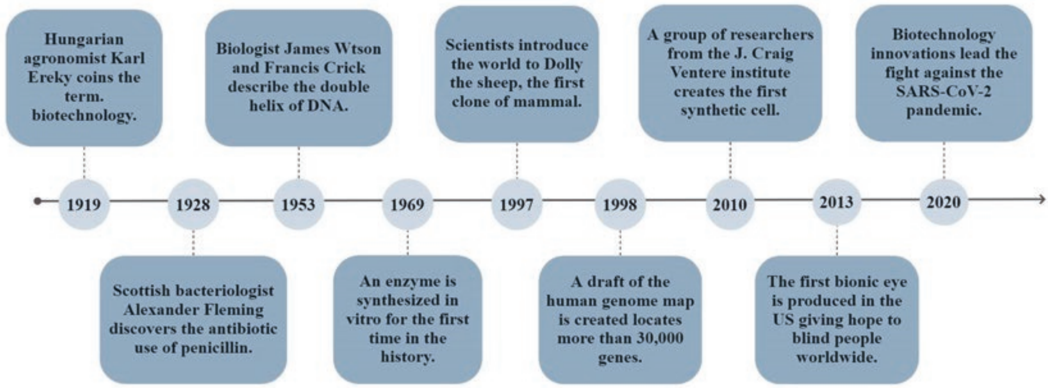


Fig. 2.20 Other milestones of biotechnology. (What is Biotechnology? Types and Applications – Iberdrola 2021)

ing and beer fermentation. Both of these processes combine the naturally occurring biological properties of wheat and yeast and use human intervention and technology to create the desired product. As scientific knowledge expanded, so did humanity's ability to understand more complex biological processes and eventually intervene in them to create new technologies.

Modern biotechnology and biomanufacturing began with the discovery of proteins in 1830. In the twentieth century, revolutionary knowledge on the structure and process of DNA allowed for rapid advancement in biotechnology. The discovery of DNA's structure helped to understand human genetic code while contributing to the foundation of genetic engineering and recombinant DNA technology (Khan 2011). By 1976, scientists developed the first working synthetic gene. This development was followed by recombinant human insulin and human growth hormone production in the late 1970s. By 1994, the susceptibility gene for breast cancer was discovered. The year 1997 marked another significant milestone when the first clone of a mammal, a sheep named Dolly, was created. Additionally, a remarkable development was achieved in 2008 when a blue rose was developed through genetic modification. Over the past few decades, there have been several other discoveries in biotechnology that could be classified as milestones, such as the invention of antibiotics and the application of selective breeding in plants and animals, which led to better crop and livestock production (Khan 2011). Other milestones of biotechnology are represented in Fig. 2.20.

As biotechnology developed and its applications increased, the field was divided into seven branches coded by seven colours, shown in the list below (Iberdrola 2021).

1. *Red:* Biotechnology in the medical field. Stem cells and gene therapy are clear examples of red biotechnology. DNA fingerprint technique is another prominent application.
2. *White:* Biotechnology applied to industry. Examples include the production of insulin to treat diabetes and the development of new enzymes. Pharmacogenomics, regenerative medicine, nanobiotechnology and biopharmaceuticals are other emerging fields of biotechnology that could be classified as both red and/or white.
3. *Green:* Biotechnology in the agricultural sector. Examples include genetically modified crops, bacteria-based plant fertilisers and pest-resistant grains.
4. *Grey:* Biotechnology is used to protect the environment. It has emerged to prevent environmental contamination and sustain the ecosystem (Khan 2011). One example is microbes that digest oil.
5. *Blue:* A defunct category for biotechnology applications in the ocean. An example application of this area is wound treatment.

6. *Gold:* Biotechnology is responsible for gathering, storing, analysing and separating biological information, particularly that linked to DNA and amino acid sequences. It is also known as bioinformatics.
7. *Yellow:* Biotechnology focused on food production. It is now being used to lower saturated fat levels in cooking oils, for example.

The types of biotechnology can also be more simply classified as animal, agricultural, medical, industrial and environmental biotechnology. Figure 2.21 represents the types of biotechnologies, and applications of biotechnology are shown in Fig. 2.22.

Biotechnology has allowed for unprecedented possibilities and potential for cures and treatments. For instance, preventative therapies are executed using medical biotechnology, which generally refers to harnessing living cells to develop pharmaceutical treatments and cures for a range of diseases and conditions. These types of technologies have been transformative in the prevention and treatment of several types of cancer (Pham 2018). Medical biotech has also played a significant role in reducing the impact of infectious diseases. The mRNA vaccines developed in 2020 to protect humans against the COVID-19 virus provide an excellent example of biotechnology developed in response to a threatening infectious disease (Jackson et al. 2020). Biotechnology has also allowed for earlier and more accurate diagnoses of diseases that are caused by genetic factors as technology now allows for genomics to analyse patients' genetic sequencing and look for risk factors and/or existing conditions based on DNA (Pham 2018).

Another revolutionising biotechnological development is genetically modified crops. Many of these genetic interventions were developed to increase food production and profits for the companies developing them. Genetically modified crops may quickly become a worldwide necessity as climate change transforms the farmland needed for agriculture and demands crops with the ability to survive droughts, increased heat, increased storms, etc.

There are numerous other products in the biotechnology area:

- Cosmetics and personal care items: Biotechnologically textured products are highly pure, non-irritating, smoother, less greasy and environmentally sustainable.
- Bread: Genetically engineered microorganisms allow for longer shelf life for higher quality bread while helping to remove potassium-carcinogenic bromate.
- Vitamin B2: Genetically improved microorganisms generate this fermentation in a single

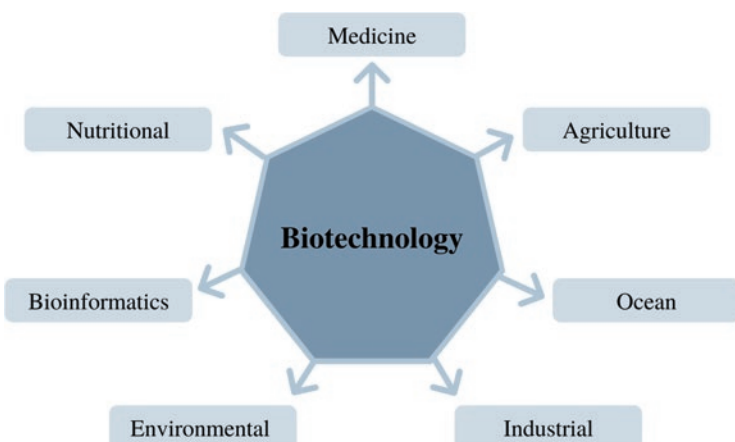


Fig. 2.21 Types of biotechnology. (Khan 2011)

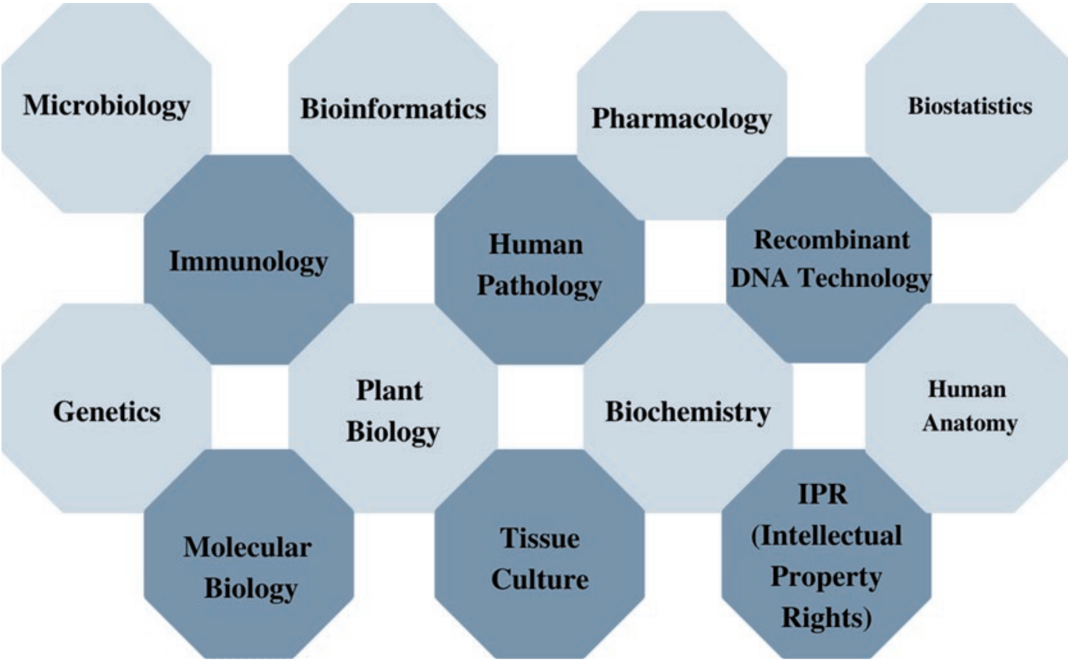


Fig. 2.22 Fields working with biotechnology. (Khan 2011)

step, which reduces CO_2 emissions and energy consumption by 33%.

- Diapers: A biodegradable polymer is created using *Bacillus*, which is environmentally and skin-friendly.
- Detergent: Proteases, amylases and lipases, which are within the biotech enzymes, assist in saving energy and cleaning clothes luminously.
- Tissue paper: With wood bleaching enzymes, the pulping process is faster, more environmentally friendly and cost-effective.
- Textiles and stonewashed jeans: The usage of biotech cellulose generates soft textiles with decent colours.
- Foam and nylon: The biotech-treated foam is utilised to create furniture and nylon to manufacture softer grade fibre tapestries that are more resistant to stain and UV light than ordinary nylon.
- Plastics: Biodegradable polymers produced with *Bacillus* microbes are highly beneficial in foods and beverages and are environmentally benign in the production of food services and containers.
- Synthetic rubber: Natural compounds are polymerised into synthetic rubber and elastomers, which are highly pure and cost-effective (Saxena 2020).

Biotechnology has always played a significant role in human life for millennia, with its importance only becoming greater over time. Medical biotechnology is already serving more than 350 million patients around the world through the treatment and prevention of everyday and chronic ailments. New fields of study emerge as technology and knowledge develop, including nanobiotechnology, bioinformatics, pharmacogenomics, regenerative medicine and therapeutic proteins (Khan 2011). Additionally, the use of recombinant organisms will have a wide range of applications, including new vaccines, solvents and chemicals. Another area that will gain importance is biochips, which are relatively more energy efficient compared to silicon chips. These products could have an impact on hormone secretion and heart rate. Gene therapy is another field that will have a rapidly increasing demand. With the help of this application, genetic diseases or

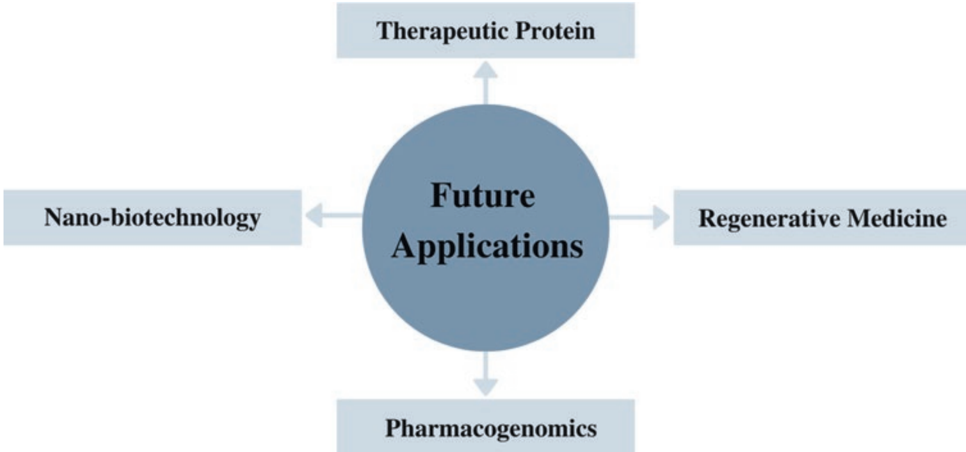


Fig. 2.23 Future Applications of biotechnology

disorders can be prevented by implementing a healthy, mutated gene (Khan 2011). Furthermore, with their environmental enhancement impacts, biotechnology and biomanufacturing will have key roles in the adoption of sustainability on a long-term scale. In this context, biological production systems, as one of the applications of biomanufacturing, are appealing because they employ fundamental renewable resources to generate a wide range of compounds using low-energy processes (Gavrilescu and Chisti 2005). Instead of finite and volatile fossil fuels, industrial biotech can assist in the fight against climate change by providing an alternative and safer source of global energy. It has resulted in significant reductions in greenhouse gas emissions and aims to reduce 2.5 billion tonnes of carbon dioxide emissions per year by 2030 (*Report on Industrial Biotechnology and Climate Change: Opportunities and Challenges – OECD* 2011). Figure 2.23 shows numerous future biotechnology application areas.

Another promising area of biotechnology is synthetic food. The effective integration of food science and synthetic biology is a key technology for addressing current food safety and nutrition issues and a key approach for overcoming the sustainability concerns associated with traditional food technology. It may be possible to eliminate the disadvantages of traditional agriculture while boosting resource conversion efficiency by incorporating synthetic biological technologies into future food. In general, the synthetic biology-driven food sector has the potential to address future food supply issues. A future food revolution powered by synthetic biology is possible in three stages. Firstly, synthetic biology can enhance traditional food production and processing. Secondly, synthetic biology can improve food nutrition or provide new functions. Thirdly, using created microbial communities in synthetic biology can change the conventional fermentation food production method (Lv et al. 2021). As a result, biotechnology is promising. We can imagine a society free of cancer, AIDS and Alzheimer's disease, as well as a world with sustainable development that addresses the energy, food and environmental demands of an ever-growing population without jeopardising either Earth's resources or future.

2.10 Blockchain

Blockchain can be defined as a technology protocol that enables data sharing with trust-based transactions such as identification and authorisation in a decentralised-distributed network environment without the need for approval or control of a central authority. In Fig. 2.24, the decentralised structure of the blockchain system is compared with other systems.

Fig. 2.24 Comparison of the blockchain system with other systems

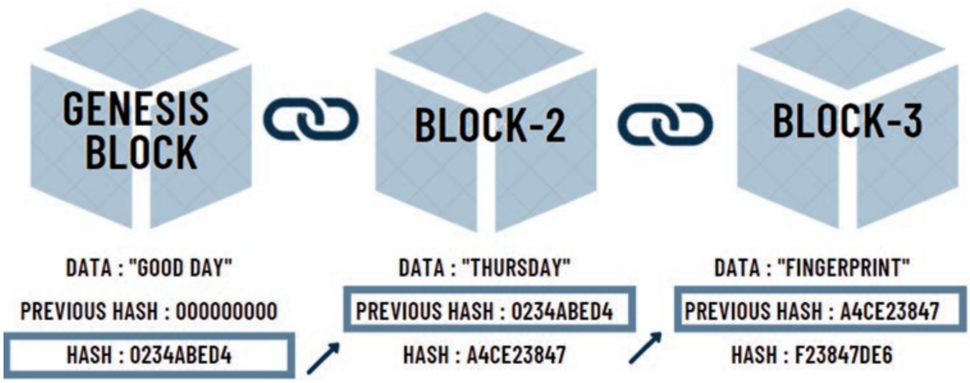


Fig. 2.25 Blockchain technology working principle

Blockchain is also defined as a database system that provides decentralised and intermediary transactions, allowing the blocks in which data is stored to be processed, stored and arranged in temporal and linear order. Produced blockchains are traded on a decentralised network structure. Due to this dispersed network structure, it becomes impossible to make theoretical changes to the data. This also helps to build confidence in the data. The distributed network structure makes the system more secure. These scattered data can be open source or closed source.

Blockchain technology has exciting implications for the future potential of decentralised structures, which includes a trustworthy and transparent trading infrastructure for peer-to-peer energy trading (Küfeoğlu 2020). Figure 2.25 shows how blockchain technology works.

Blockchain does not offer editing on legacy data. Therefore, it works not like traditional databases but as a digital ledger where transactions are listed one after the other. In the blockchain, transactions are stored in blocks, and each newly created block refers to the previous block with a unique identification number called a "hash". Because each block is cryptically linked to the previous one, changing any of them changes all subsequent blocks.

Within the global and fast-paced system, it is seen that both companies and countries are trying to catch up with digital transformation with their efforts to expand their field of activity. The most important feature that ensures its reliability is that a saved database cannot be changed or corrected again; with this aspect, it would not be wrong to say that blockchain is not a database but a data recording system. In this way, users can connect to the network, perform new transactions, verify transactions and create new blocks without intermediaries. Blockchain technology proposes several advantages such as increased security, transparency, high speed, low cost and decentralised nature.

(i) *More Secure*

Blockchain technology provides a layer of security by using cryptography to the data saved on the network. The decentralised aspect of blockchain provides superior security because it is combined with encryption. Blockchain is a decentralised and cyberattack-resistant database. It is not possible to change the history of the ledger or send the same transaction twice (i.e. double-spend) as every transaction ever made on the network is recorded and stored permanently. This certainty creates mutual trust. Congestion management using electric vehicles in grid services; energy data registration in a secure medium as an open ledger; and billing, switching providers, swapping capacities and so on are just a few examples of how blockchain technology can be employed (Dena 2019).

(ii) *Transparency*

Everyone, not just its users, has access to the blockchain database. As a result, the control is visible. A block's transactions, wallet addresses, transaction ID (shipping code) and quantities may all be viewed by anyone. Open blockchain networks are truly "open". For example, in the Bitcoin network, it is possible to see all the blocks created to date and the money transfers in them. All transaction information can be accessed via Blockchain.com.

(iii) *High Speed and Low Cost*

Due to its fast and low cost in health, food, forensic cases and keeping records of international companies, blockchain technology leaves traditional methods behind one by one. The most important reason for this is the transfer of data directly from one user to another quickly and cost-effectively. Transactions, especially international transactions, take seconds rather than weeks to complete.

(iv) *Decentralised*

The revolutionary feature behind blockchain is that transactions are completed not one by one but by many computers at the same time. All computers reside on the same network called a peer-to-peer network (P2P). This model is often referred to as the "distributed trust model". Figure 2.26 shows the advantages of blockchain in general.

Three features of blockchain technology come to the fore. They are a distributed architecture that ensures that a copy of each data is kept on thousands of nodes in the network. The transparency allows for the tracking of all transactions made on the network. Immutability that prevents processing of the data produced to the blockchain. With these features, blockchain is a candidate to be the backbone of the new Internet structure.

Blockchain offers groundbreaking technologies that have the potential to change the Internet and even the world for many reasons. Participants can share excess energy and purchase or sell carbon credits using blockchain's revolutionary P2P energy trading platforms (Küfeoğlu 2020). One thing is certain: blockchain technology is ushering in a new era of digital information sharing, as

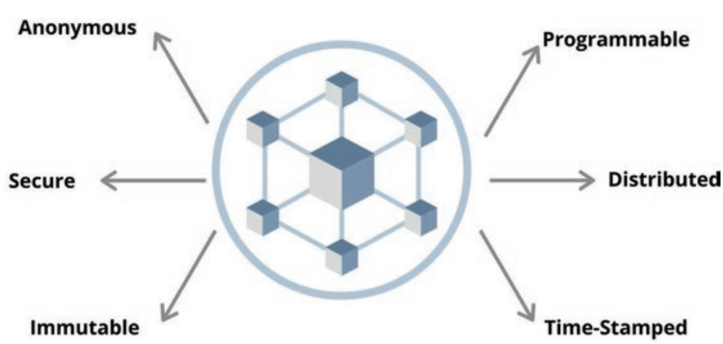


Fig. 2.26 Advantages of blockchain

well as a novel means of data storage and transaction representation. Blockchain technology offers alternative methods to solve the heavy paperwork process, delays, incorrect transactions, high costs, fraud and many more problems on the logistics side. It is possible to design functional systems by integrating international trade with blockchain technology. Over $1 billion was invested by venture capitalists in 215 blockchain-based firm deals in 2017 (CBINSIGHTS 2018). The technology is highly promising in delivering a secure and trustless transaction and data storage medium. By 2027, it is predicted that blockchain would have stored roughly 10% of the global gross domestic product (World Economic Forum 2015). The technology can be utilised in a wide range of areas and businesses such as banking and payments, data security, voting and elections and energy and distribution networks.

(i) *Banking and Payments*

There are still many obstacles to a perfect financial sector, whether it is identification or fraud difficulties in developed countries or security issues in areas where technology is not widely used. Blockchain has the ability to tackle these issues in a revolutionary way, benefiting every element of the industry.

(ii) *Data Security*

Messages and data are encrypted with a cryptocurrency that uses a public key infrastructure (PKI). Personal information is less likely to be revealed and replicated via this way.

(iii) *Voting and Elections*

Blockchain has the potential to play a significant role in digital transformation, allowing citizens to vote from the comfort of their own homes or from anyplace else. Vote stealing may be prevented at every level with fast and precise verification and accurate vote counting. It will be impossible for a person to vote with personal identification numbers more than once. Systematic breaches will be detected quickly because of the distributed ledger.

(iv) *Energy and Distribution Networks*

Blockchain enables people to share extra energy and buy or sell carbon credits through revolutionary peer-to-peer energy trading platforms. This paradigm shift towards decentralised local energy exchange via peer-to-peer (P2P) will drastically minimise transmission losses while also deferring costly network upgrades. Unlike centralised architectures, the blockchain distributed ledger does not require the intervention of third parties to preserve the system's integrity and security. Blockchain is a distributed ledger that employs automated technology to create smart contracts that improve cybersecurity and optimise energy operations, lowering transaction costs considerably (Küfeoğlu 2020). Individual customers may be able to swap electricity and make payments in a frictionless manner thanks to blockchain's decentralised transaction verification. Better network and congestion management and the challenge of renewable generation intermittency can all be aided by digitalisation, allowing for more efficient network operation and more effective network monitoring (Küfeoğlu et al. 2019).

Blockchain technology, as a unique technology that creates a new consensus process to eliminate a single central authority, could be very valuable in energy trade (Küfeoğlu et al. 2019). Some peer-to-peer energy marketplaces are built on the blockchain platform, which allows all transactions to be authenticated and stored permanently without the need for a central authority (Küfeoğlu et al. 2019).

2.11 Carbon Capture and Storage

The concentration of uncontrolled dispersed CO_2 may cause crucial climate change as an increase in average global temperatures. It is estimated that carbon dioxide emissions around the globe will be higher in 2050 than they were in 2018. Forecasts indicate that CO_2 emissions will increase gradually every 5 years and will exceed 40 billion metric tonnes from 2045 (Statista 2019). Carbon capture and storage (CCS) tech-

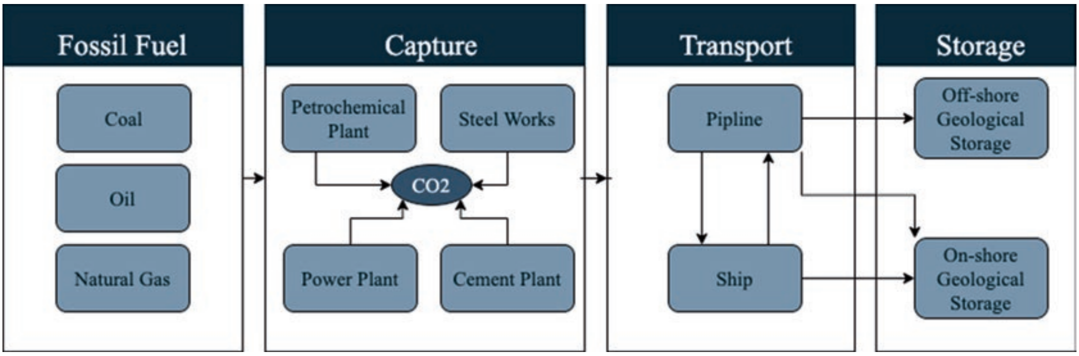


Fig. 2.27 Carbon capture and storage phases

nology has emerged to mitigate climate change by reducing CO_2 emissions (Singh 2013). The first large-scale project on CO_2 capturing was planned to enhance produced oil by injecting CO_2 and increasing the pressure on the oil reservoirs in the 1970s (IAE 2016). The increase in oil and gas production through injected captured CO_2 has revolutionised the energy sector, and the importance of carbon storage has also expanded. Although CCS is used to increase production, it has become one of the agenda items of many countries since it is known that the long-term effects of CO_2 released after this production on global climate change will be substantial. While CO_2 emissions dropped dramatically by 5.8% in 2020, the demand for fossil fuels in 2021 seems to reverse this situation. A 4.8% increase in CO_2 emissions is expected in 2021, with demand for coal, oil and gas recovering after the temporary impact of the pandemic (IAE 2016). Most of the CO_2 emissions are caused by the use of fossil resources. The intensive use of coal, natural gas and oil in power plants, industrial facilities, vehicles, residences and workplaces to meet energy and heating needs are the biggest cause of the emission problem. The use of these resources releases large amounts of greenhouse gases into the atmosphere. Increasing livestock farming, cutting down trees, etc. are other causes of increased CO_2 emissions. However, their impacts are not as notable as fossil fuels and applying CCS for these causes ensures emission reduction in the longer term. In this regard, CSS methods are mostly focused on fossil fuels. Figure 2.27 illustrates the CCS stages in detail.

Many research and development projects for CCS have been established among the presented cases in many countries. Lawmakers primarily aim to reduce carbon emissions for measures related to climate change. Governments and companies have adopted carbon-neutral methods to reduce this impact of fossil fuels, which have an equal balance between emitting carbon and absorbing carbon from the atmosphere in carbon sinks (European Parliament 2019). In this direction, incentives and orientations towards carbon-neutral technologies are increasing, together with regulatory methods such as carbon tax and carbon footprint monitoring. However, carbon-neutral methods are still not enough in line with climate targets. Countries that have committed to zero carbon emissions until 2050 at the Paris Climate Summit have started to use carbon-negative methods and carbon-neutral methods to achieve this goal. Carbon-negative methods aim to reabsorb more carbon dioxide released into the atmosphere than disseminated (IEA 2020). Although it is difficult to withdraw more carbon than is emitted today, carbon-negative methods have a significant role in reducing the amount of carbon in the atmosphere. Among the most common carbon-negative methods are carbon capture and storage technology.

(i) *Carbon-Capturing Methods*

The main CO_2 capturing technologies are chemical and/or physical absorption, physical adsorption and membrane separation. Carbon capture is a technology with multiple methodologies, but its basic logic is based on the separation of free CO_2 from the air. The capture of CO_2 could be classified into three types, i.e. post-combustion capture, pre-capture and direct capture (Kuckshinrichs and Hake 2015). The fuel is not directly burned in pre-combustion capture but transformed into synthesised gas at the appropriate temperature and pressure. Afterwards, CO_2 is transformed into carbon dioxide and H_2, and CO_2 is collected for H_2 as the fuel (Rackley 2017). CO_2 is captured from the industrial process waste into a nearly pure CO_2 stream in post-combustion. (e.g. cement plant flue gases). In direct capture, pure CO_2 is captured directly from the air (e.g. mineralisation of steel slag) (Goel et al. 2015). The separated CO_2 could be used for different purposes such as soda ash production, oil drilling and alternative energy sources production. Thus, the storage of captured carbons has great significance. Figure 2.28 articulates these carbon capture methods.

Geological storage is the most used method to store carbon. First of all, carbon is captured in different ways. Then it is injected into different geological forms like oil and gas reservoirs, saline forms, unmineable coal seams and basalt formations. CO_2 is stored by impermeable caprock (Rackley 2017). By significant developments of technologies in the injection industry, geological storage is in oil and gas reservoirs preferred by companies to store carbon. Stored CO_2 is also utilised for unmineable coal because its molecules could easily interact with the coal surface. The main problem for geological storage is transportation cost. Although it is not necessary to construct storage facilities, it is important to invest in transportation infrastructure to deliver CO_2 to these facilities. Ocean storage is one of the greatest storage since oceans are major candidates to store captured CO_2. However, storage must be in-depth not to release CO_2 into the atmosphere. Direct dissolution is sent by ships with pipes to deep waters at supercritical fluid, and it creates CO_2 lakes in the depth of the oceans. Creating CO_2 lakes in the oceans is an efficient method for long-term storage (Rackley 2017). Mineral storage is suitable with the law of thermodynamics so it can occur in nature without any application by humans. CO_2 reacts with metal oxides and produces stable carbonates. This process takes over a long timescale in nature. When this process operates at higher temperatures and pressure, it can be accelerated, creating energy costs (Rhodes 2012).

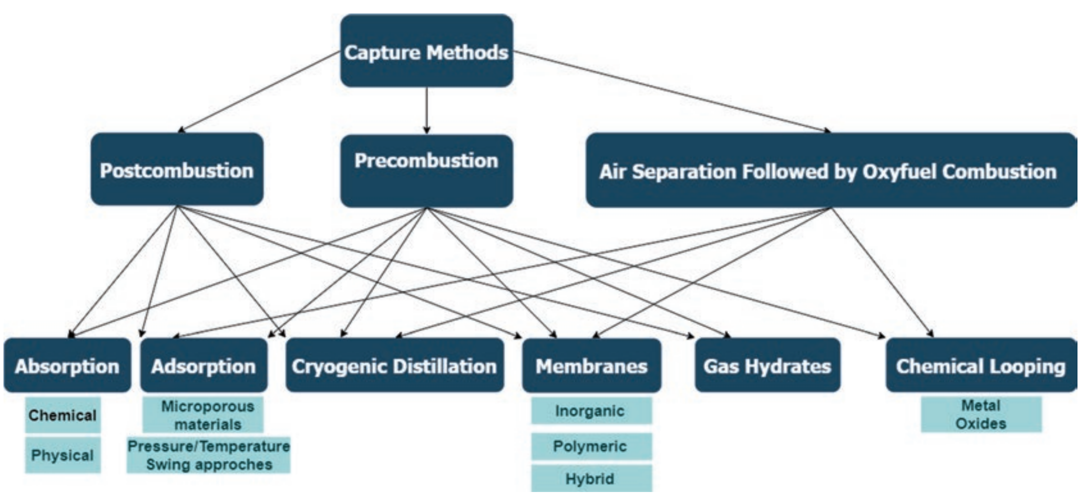


Fig. 2.28 Carbon capture methods. (Creamer and Gao 2015)

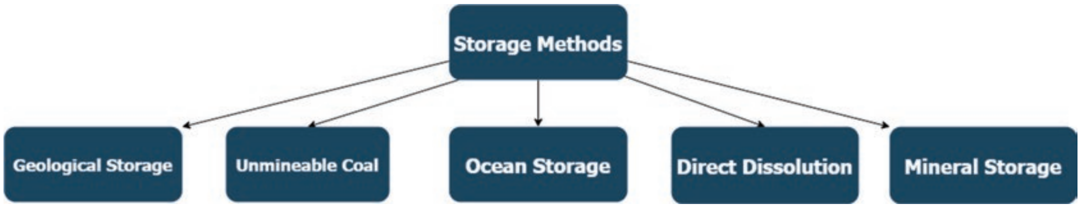


Fig. 2.29 Carbon storage methods

Although CCS is a useful technology, it has not received the necessary response in the industry due to its cost. The high unit and technology costs are among the main reasons why the private sector does not invest in this field. Incentives from governments, reduction in technology costs and private sector investments in this field play an important role in the future of CCS technology. In sectors where carbon capture is easy, and CO_2 is heavily emitted, CCS technologies perform more efficiently and more economically. Examples of these are the cement, iron and steel and refinery sectors. In addition, decomposed CO_2 has great importance, and it needs to be used or stored without being released back. The most suitable areas for storage are oil reservoirs. In addition, this storage method is used to increase oil production by pumping it into the oil deposits stuck between the layers. Figure 2.29 illustrates the abovementioned storage methods.

The efficiency of carbon-capturing technology may be as high as 90% when it comes to capturing the CO_2 that is released from industrial processes. These industrial processes are in a broad spectrum, from the energy sector to manufacturing and construction. Among all, the energy sector is covering the highest percentage when it comes to carbon-emitting, by almost 40%, when examined globally (Leung et al. 2014). Steps of capturing, storing and utilising carbon are crucial to the environmental act against global warming by reducing and preventing the negative effects at some level. Overall carbon emissions may be negative with a combined strategy of capturing carbon and utilising biomass. In addition to the contribution of the global warming fight mentioned above, calculations indicate that CCS's contribution to emission reduction attempts may be needed to reach a percentile of 14 to keep the globe's temperature at a certain level of 2 °C or less by the year of 2050.

Renewable energy, which has become increasingly important, cannot meet the rising energy demand on its own, and it seems that fossil fuels will still play an important role. According to Jackson, although renewable energy is now considered the most cost-effective source of power generation worldwide, the growth in energy demand and the growth needs of governments indicates that fossil fuels will continue to play an active role (Jackson 2020). In the future, CCS technology appears to grow more and become crucial in terms of maintaining the environmental balance by absorbing CO_2 while supplying energy demand from fossil fuels. Aiming to benefit from the ecological and economic advantages of CCS, the UK government will provide £1 billion in funding to support the development of four CCS centres and cluster projects across the UK by the end of the decade (Kelly 2020). Furthermore, the Norwegian climate solution will heavily rely on CCS with developed versions of the technology. Equinor, Shell and Total are investing in the Northern Lights project, which is Norway's first CO_2 storage licence and a key component of the Norwegian government's "Longship" strategy (Equinor 2020). Canada is another country investing in Direct Air Capturing (DAC) technology. *Carbon Engineering* states that DAC technology can be scaled up to remove up to 1 million tonnes of CO_2 per year from the atmosphere in Canada (Jackson 2020). In addition to recent developments mentioned above, Climeworks, one of the CSS companies, expands its direct air capture and storage technology, making a permanent CO_2 removal solution more readily available. It includes the infrastructure and foundation of the next generation of Climeworks CO_2 collectors.

Their solution includes the installation of plants and machinery in Iceland and is expected to be completed in spring 2021. What makes Climeworks' use of DAC so intriguing is that it can capture pollutants straight from the air, rather than merely eliminating emissions connected with electricity generation, and also this is the company's largest facility to date, with a CO_2 collection capacity of about 4000 tonnes per year (Jackson 2020). As a result, CCS technology will gain even more importance and develop in the coming years. CCS seems like a viable solution to address the climate change problem.

2.12 Cellular Agriculture

Throughout the years of extortion of natural resources, possible new solutions to neutralise the effects started to emerge. First, a decrease in consumption was suggested. Other suggestions included using less water to preserve the resources, less plastic and more biodegradable resources to prevent pollution and so on. Among many topics, the consumption of meat has always been on the agenda. Setting aside the ethical arguments, meat consumption is not sustainable in many ways and causes substantial global warming. At this point, cellular agriculture steps forth as a remedy. This technology focuses on the production of an animal product-like substance that does not harm the environment in the process of production or consumption. This substance is produced from cell structures rather than animals. Using advanced biotechnology, tissue-based products like meat (of fish, cattle, sheep, goats, chicken, turkey, etc.) and protein-containing foods like eggs and dairy products become available alternatives. Focusing on both sustainable food production and the safety of food, cellular agriculture uses many techniques to imitate and meet the standards of nutritional values while being almost carbon neutral.

A. *Cell Cultivation*

Cell culture takes cells from a plant or animal and grows them in a controlled environment. The cells can be extracted directly from the tissue and crushed enzymatically or mechanically before being cultured, or they can be replicated from a cell line or cell strain. The primary culture phase begins after the cells have been separated from the tissue and multiplied under optimal circumstances until all substrates have been occupied. To provide more vacancies for growth, the cells must be subcultured by transferring them to a new case containing fresh growth. The primary culture is referred to as a cell line or subcloned after the first subculture. Cell lines are reproduced from primary cultures which have a limited lifetime, and when they are crossed, cells with the highest growth capacity dominate. As a result, genotype and phenotype will be uniform (Invitrogen and Gibco 2021). This cell line becomes a cell strain when a subclone's subpopulation is positively selected from the culture through cloning. Following the commencement of the parent line, a cell strain frequently acquires further genetic changes. Culture conditions are variable for each cell type, but the environment generally contains essential nutrients, hormones, enzymes and gases that are necessary for substrate (Invitrogen and Gibco 2021). Figure 2.30 presents the stages of cellular agriculture with cell cultivation.

B. *Precision Fermentation*

The second method in cellular agriculture is precision fermentation. This method uses microorganisms to obtain the proteins in animal products. This method can be explained in four steps:

1. Introduce: Firstly, a gene from a farm animal is introduced, for microorganism production, to a host cell optimised to produce an animal protein kind of yeast. Integrating this gene from farm animals into the host cell will instruct the host cell on how to create specific animal proteins.
2. Feed: Secondly, the production of animal proteins at the cellular level starts after the implementation of those farm animals' genes to host microorganisms' cells. Host cells need nutrients to ensure that the cellular agriculture

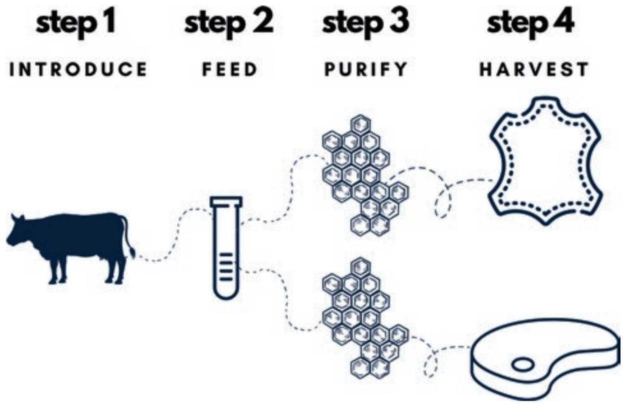


Fig. 2.30 The method of cellular agriculture with cell cultivation. (Cellular Agriculture Society 2021)

process takes place properly and for its continuation. You need to feed the host cell nutrients in a controlled environment called a fermentation cultivator.

3. Purify: After the production of animal proteins is completed, the host production cells must be removed. Thus, only animal proteins remain in the final product. Only the final purified animal proteins remain after the host cells are separated from the produced proteins.
4. Harvest: In this final step, animal proteins go through the post-processing steps. After rigorous testing for safety and quality, a real animal product is ready to be harvested (Cellular Agriculture Society 2021).

Figure 2.31 presents the stages of cellular agriculture with precision fermentation.

It is possible with cellular agriculture to benefit from animal meat without the need for animals. The current system can produce animal meat that is enough to cover the existing consumption rate, but it will be unable to do so in the future due to factors such as increasing population. Experts estimate that the human population will be 9–11 billion in 2050 (UN 2017). Increasing population means increasing food needs. Thus it seems that animals alone will not be enough for humans. Rather than encouraging consumers to choose plant-based diets more, the other ideal solution is the innovative improvements in meat production, which stands out as the task of cellular agriculture. There are three main benefits of cellular agriculture: benefits for the environment, benefits for the animals and benefits for human health. Figure 2.32 demonstrates some benefits of cellular agriculture.

The huge quantity of resources required by livestock farming has a wide environmental impact. It is astounding how much water, land and power livestock use. Khan states that in addition to the 1.6 kg of feed necessary to make a 0.23-kilogram steak, the manufacturing process necessitates 3515 litres of water and just as much energy is needed to charge a laptop as much as 60 times. Moreover, different greenhouse gases are released into the atmosphere containing a total of 4.54 kg of CO_2, which is equal to 2 litres of gasoline. This data represents what is needed to make an 8-ounce steak and not the entire animal. Roughly 25% of the surface of the world is dedicated to livestock. This is approximately 70% of all agricultural land (Khan 2017). Furthermore, animals consume around 30% of the world's freshwater. Livestock account for 14.5% of all emissions of greenhouse gases. Cellular agriculture promises to minimise global greenhouse gas emissions and to encourage more ethical usages of natural resources. Cellular farming is an eco-friendly and sustainable option in comparison with animal production. Fleece made from cellular farming requires less than 1/10 of the land and water (Khan 2017). The greenhouse gas emissions in this beef will also be considerably reduced. The number of animals required in the production process is reduced due to cellular agriculture, eliminating livestock. With the

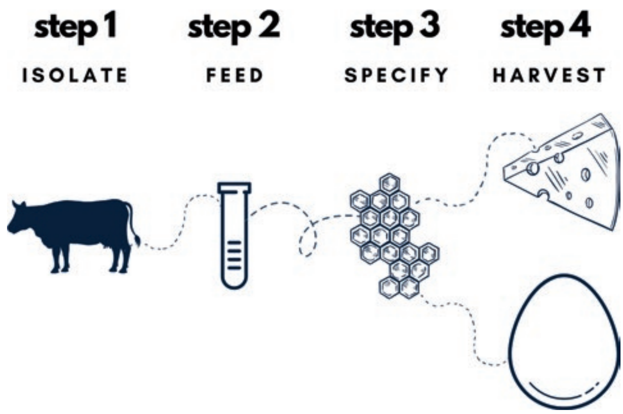


Fig. 2.31 The method of cellular agriculture with precision fermentation. (Cellular Agriculture Society 2021)

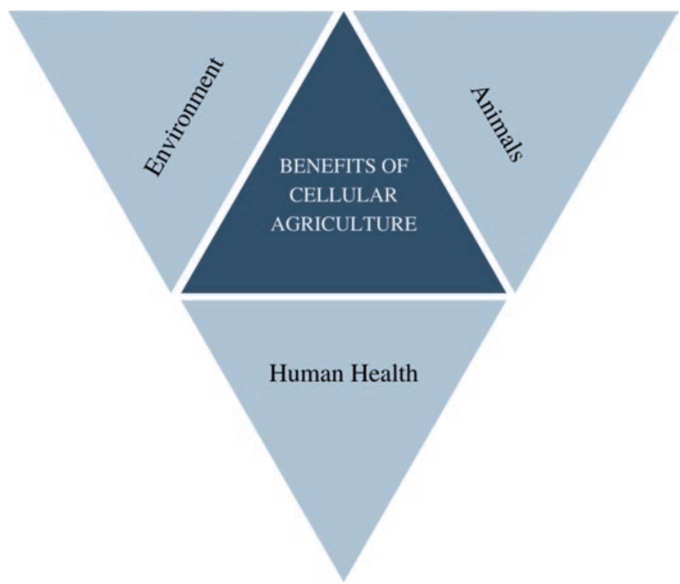


Fig. 2.32 Benefits of cellular agriculture

increasing population, the demand for meat is increasing even more. On the other hand, meat production facilities quickly raise animals under unsanitary conditions to produce more meat without due concern given to animal welfare (Khan 2017). Cellular agriculture is among the most effective solutions to fulfil the increasing meat demand while ensuring animal welfare. About 80% of all antibiotics sold in the USA are used in animal agriculture. This situation increases antibiotic resistance in humans and causes various health problems. For instance, most bacterial contaminants, *Salmonella* and *E. coli*, that cause food-borne diseases commonly interact with contaminated animal excrement (Röös et al. 2017). Bacterial contaminants like *Salmonella* or *E. coli* will not be the case in cellular agriculture since no livestock will contaminate the meat or other goods.

Meat production has long been the subject of controversy. Animal rights activists think that obtaining meat from animals is a massacre, and they look for other ways to meet their protein needs without eating meat. For example, they turn to a vegan and vegetarian lifestyle. However, cultured meat, the most popular topic of cellular farming, could change this. Cultured meat comes as an alternative for its ecological and animal welfare benefits and to feed humanity's growing population. Besides all the environmental bene-

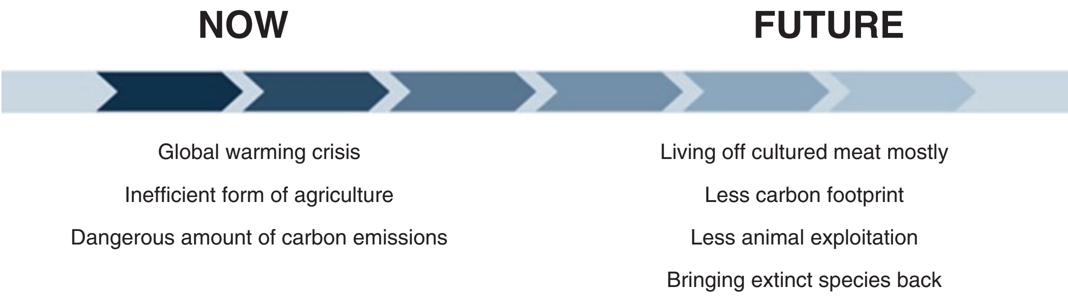


Fig. 2.33 Motivation for cellular agriculture

fits, cultured meat is also healthier than normal meat because it is produced under laboratory conditions in a controlled manner. Cultured meat does not contain bacteria and other disease-causing agents. While plastics/microplastics are seen in normal meats, they are not seen in cultured meats (Gasteratos 2019).

Humanity continues its search for life on another planet. People have long kept their eyes on the Moon and Mars. The long-term missions have been targeted, and there is a basic problem in meeting the protein needs of astronauts. Experts have invested in cultured meat for a long time to solve this problem. If colonies are established on the Moon and Mars in the possible future, keeping human beings alive is planned by using cultured meat. Israel-based company Aleph Farms aims to accelerate cell-based meat production in space. Aleph Farms says that “We want to make sure that when people live on Mars, we’ll be there too” (Morrison 2020). In this respect, cellular agriculture is most likely to be on the main agenda in the future.

Gareth Sullivan, deputy director of the University of Oslo’s Hybrid Technology Hub, is experimenting with technology to generate stem cells from endangered species such as the northern white rhino. According to Labiotech, working with Ian Wilmut, one of the scientists who cloned Dolly the sheep in 1996, the researcher obtained a fundamental grasp of stem cells. Stem cells from endangered animals are being stored for a future in which technology can bring extinct species back to life. The project received an investment of €220,000 from the Good Food Institute, which conducts vegan and cultured meat R&D (Smith 2021). Figure 2.33 demonstrates the present and future motivations for cellular agriculture.

2.13 Cloud Computing

Cloud computing is a technology that provides elastic and scalable computing techniques to fulfil information technology capabilities delivered in varying service models through the Internet. Moreover, it is an easy way to share the folders with other people and work by collaborating with them via the Internet from the personal computer or network servers. This sharing can be private or public. Cloud computing technology generally includes many clouds, and these clouds communicate with each other through application programming interfaces and using web services (Mirashe and Kalyankar 2010). Cloud computing is quite popular among researchers, citizens and governments nowadays. One of the reasons for this is that when the memory of personal computers is full, it indirectly inhibits speed and performance. To prevent this, a personal account is created by transferring personal data to computers with a lot of memory via the Internet. Thus, both storage space and computer resources can be acquired without sacrificing the personal computer’s memory. Since the main consideration behind cloud computing is to minimise the burden on the terminals of the user, cloud storage, as one of the subdisciplines of cloud computing, comes forwards in line with this purpose. Cloud storage services can provide both data storage and business access. It consists of necessary stor-

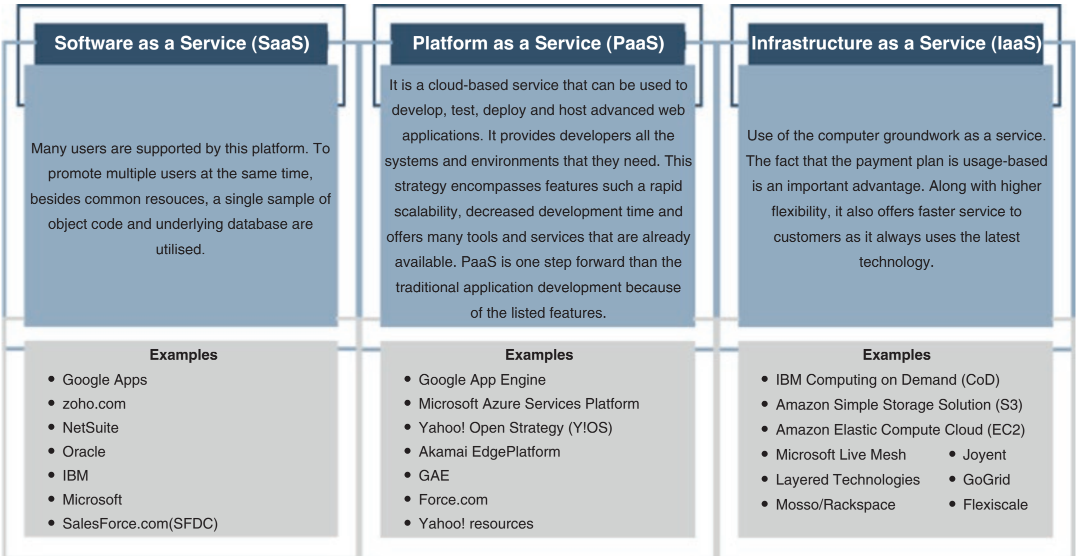


Fig. 2.34 Cloud providers and some example establishments. (Dillon et al. 2010)

age devices, and it huddles all of them together in the application software for usage. As a result, it can be thought of as one of the cloud computing systems responsible for large capacity storage (Liu and Dong 2012). Many companies, such as Microsoft Azure, Amazon Web Services (AWS), Rackspace and GoGrid, provide particular cloud computing services (Chopra 2017). Anyone can benefit from these services for a monthly subscription fee. In other words, this service can be thought of as renting a computer with very high memory and performance far away from the users themselves. It is especially useful because it does not require physical hardware to perform computation or storage. Since the data is stored and the other resources are available on the Internet, the data is always accessible anywhere and anytime as long as there is an Internet connection (Huth and Cebula 2011).

Although cloud computing provides ease of use to users, it is a modular technology with a very different operating system. Therefore, to understand what cloud computing is exactly, it is also important to understand how to choose the cloud providers. However, first of all, it is necessary to talk about what cloud providers are. Each provider offers specific functionality that gives users more or less control, depending on its type. Therefore, choosing the right provider becomes important. There are three service providers in total. These can be listed in Fig. 2.34 as software as a service (SaaS), platform as a service (PaaS) and infrastructure as a service (IaaS).

According to the user, there are different types of clouds present. The public cloud is accessible to any user that has an Internet connection. Private cloud is created for a group and/or organisation. Only that group and/or organisation can access this type of cloud. Community clouds can be shared between more than two organisations with requirements similar to one another. Lastly, hybrid clouds are formed when more than two clouds with various types or the same type are merged (Abualkibash and Elleithy 2012).

There are a lot of advantages and disadvantages to using cloud computing as all technologies which we use. The disadvantages of cloud computing are: it cannot work without the Internet or in low-speed Internet environments; sometimes the features may not be enough; the stored data may not be reliable because it is opened to the Internet if your password or cloud account is lost (Mirashe and Kalyankar 2010). On the other hand, cloud computing offers various advantages to its users. It makes the idea of connection via the Internet quite appealing over a connection through immovable physical hardware. According to Lewis (2010) and Hurwitz et al. (2012), listed below are some features of cloud computing that describe its prominence for organisations, companies and general users:

- *Availability:* Users are allowed to reach their documents and resources at any time via the Internet.
- *Collaboration:* Users can work at the same time and share the necessary and common information that they need.
- *Elasticity:* Resource utilisation of a user, which can be shaped according to the changing needs, can be transparently managed by the service provider.
- *Lower infrastructure costs:* Public cloud users can choose whichever resource that they want to use, and they pay per use. This results in no payment for the maintenance or upgrade of the hardware and software of the corresponding resource.
- *Mobility:* Networked access to the resources and information makes the attainability of the cloud by the user globally, from the places where there is an Internet connection possible.
- *Risk reduction:* Some check tests and demonstrations applied in the cloud can help organisations to examine their ideas and concepts, deciding whether to invest in that technology or not without incurring big upfront expenses.
- *Scalability:* A variety of resources supplied by cloud providers can be scaled according to the demands of the corresponding cloud users.
- *Virtualisation:* Regardless of how users utilise a resource's installed software and hardware, the provider can serve way more users with less physical hardware installed. The hardware of a certain resource can serve many users at the same time.
- *Security:* In an unlikely event, such as the loss of a file on the device when the corresponding device is damaged, it will remain in the account and safe in the cloud system.
- *Device performance:* The speed and performance of the computer used, depending on the memory, are not adversely affected since all the necessary sources are kept in the cloud.
- *Quick entry to market:* In contrast to a traditional strategy that includes purchasing hardware and software, cloud infrastructure and services may be installed fast. As a result of the preceding argument, a business can bring new items to market faster than competitors who rely on their infrastructure.

Apart from the general advantages of cloud computing, it can also be seen as an auxiliary technology to other emerging technologies. The importance of cloud computing is seen in spheres like IoT, serverless computing and quantum computing technologies.

IoT Technologies Smartphones, televisions, smartwatches, household appliances, sensors for systems such as "smart home", "smart city" and more are among the gadgets ("things") connected to the Internet. All of these devices communicate with one another or with the control software, often without the need for human participation. The more IoT turns into an autonomous system, the Internet within the Internet, the more this will accumulate huge amounts of data in real-time.

Serverless Computing Platform as a service (PaaS) is becoming more common in the software development world. The customer does not need to worry about server hardware or operating system administration because computer resources are automatically scaled as the load increases or falls. AWS Lambda, for example, is a platform that works on the premise of event-driven computing, in which the appropriate pool of resources is assigned in milliseconds in reaction to an event, such as the addition of a new code module.

Quantum Computing Quantum computers are the next step in the evolution of traditional supercomputers. Such computers are planned to be used primarily for working with large amounts of data. At the same time, both data and computing resources (qubits) can be placed in the cloud.

Since the cloud providers supply the cloud service, reliability is an issue in cloud computing.

Providers should offer decent performance with reliability. One cloud service that provides reliability and resilience with decent performance is called “reliability as a service (RaaS)”. Deep and machine learning is expected to be used in RaaS for failure prediction. Failure datasets will be used to characterise failures, leading to the development of a failure prediction model. This will be an opportunity to provide a failure-aware resource guaranteeing reliability and decent performance (Buyya et al. 2018). Another possible application of cloud computing will be based on SDN. It seems that the capability of SDN to shape and optimise network traffic will affect the studies on cloud computing (Vahdat et al. 2015). Due to workload/resource fluctuations or features, the renting fee of the cloud resource cannot be predicted by the user beforehand, which creates a necessity for tools to resolve this problem. With demand from the big data community, it is understood that the cloud environment requires new visualisation tools to be explored (Buyya et al. 2018). Other future research expectations and future-oriented cloud computing applications are summarised in Fig. 2.35.

2.14 Crowdfunding

Crowdfunding has been around for a century, but a British rock band launched the first successful crowdfunding campaign for a tour with the help of online donations from fans in 1997. Crowdfunding is the collaborative method to raise cash through friends, families, consumers and individual investors. This method uses people’s collaborative efforts – mostly online through social and crowdfunding media – to leverage their networks to reach them more widely. It is initiated by developing the accurate product to be funded and providing a solid history of its development, producing a unique video for a crowdfunding platform and establishing a monetary objective. Figure 2.36 shows the successful execution of a typical crowdfunding campaign, and Fig. 2.37 illustrates the components and outline of the crowdfunding concept.

There are four main types of crowdfunding: first, equity-based crowdfunding is the real capital exchange of private corporate shares. In this type, businesses are allowed to set investment ceilings, minimum pledge amounts, etc. and accept or reject investors interested in viewing their business paperwork. Second, reward-based crowdfunding is the most popular and useful kind of crowdfunding. This form of crowdsourcing requires the determination of several levels of awards that match the commitments. Third, peer-to-peer lending-based crowdfunding allows businesses to collect cash in the form of loans to repay lenders on a predefined schedule with a specified rate of interest. With crowdsourcing donations, campaigns accumulate donations without providing value in return. This kind of marketing is great for social reasons and charity. Lastly, donation-based crowdfunding is to raise money from other individuals for charitable causes. Campaigns are often 1–3 months in length and work well for amounts under $10,000 (Hossain and Oparaocha 2017). Table 2.2 summarises the characteristics of equity crowdfunding, rewards-based crowdfunding and peer-to-peer lending.

The investment of crowdfunding is an alternative money source for companies that ask numerous investors to invest for a small amount. Then, investors receive the company’s equity shares (Chen 2021). The 2015 Jumpstart Our Business Startups Act (Jobs Act) declared that it is allowed for diverse types of investors to invest with crowdfunding when the investment infrastructure is better (Securities and Exchange Commission 2015). It has been said in the crowdfunding industry report for 2019 that the food and beverage, health and beauty categories are the fundraisers’ leaders. Figure 2.38 demonstrates the share of industries where crowdfunding is applied.

Also, investments through crowdfunding may open an opportunity to avoid debt. A large group of backers invest in the company knowing the purpose of the loan and interest rate. A higher interest rate is received than the market rate by lenders (Chen 2021). Companies choose to crowdfund when the other debt instruments are too costly or cannot get credit from financial institutions because of credit default swaps.

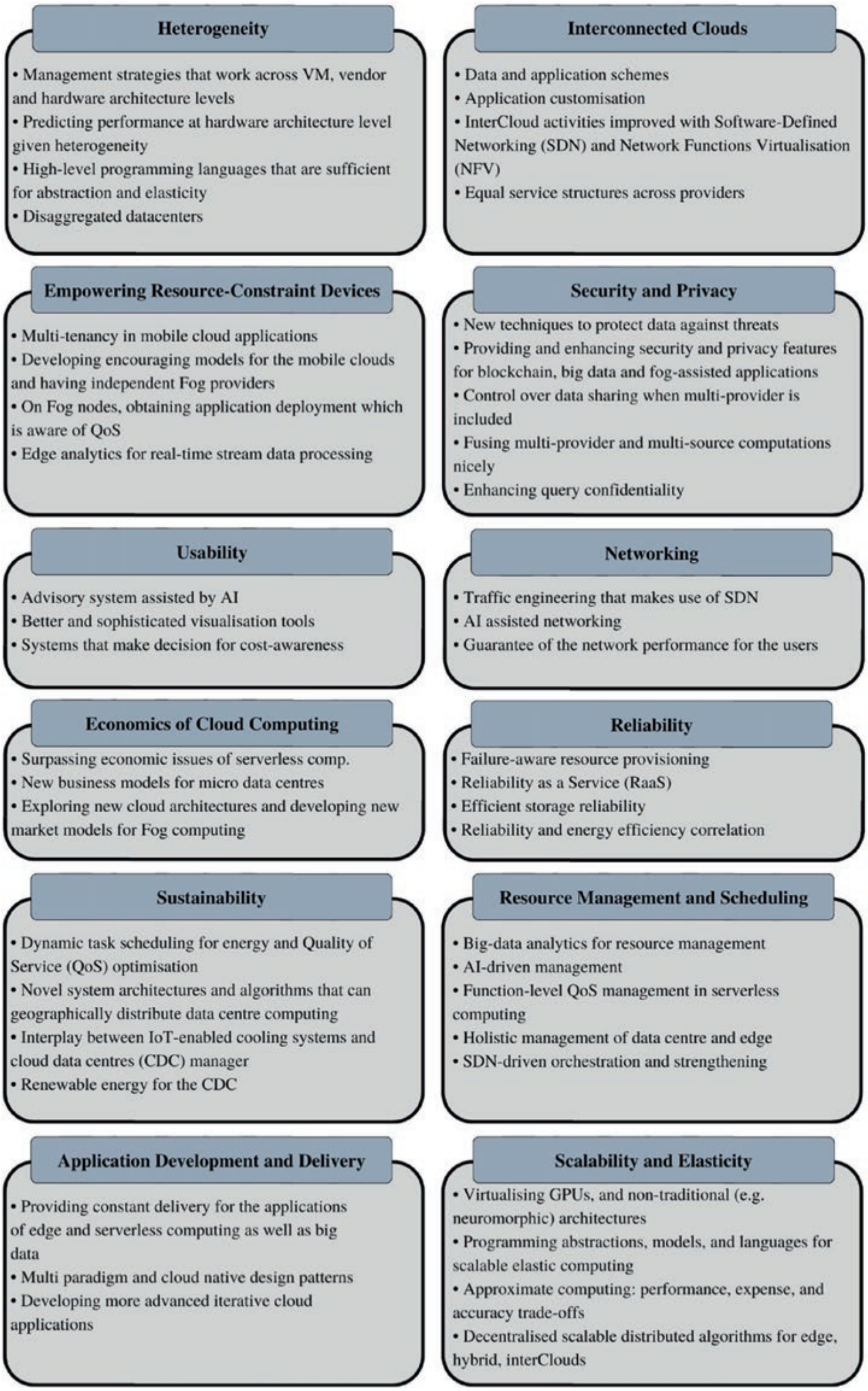


Fig. 2.35 Future directions of cloud computing. (Buyya et al. 2018)

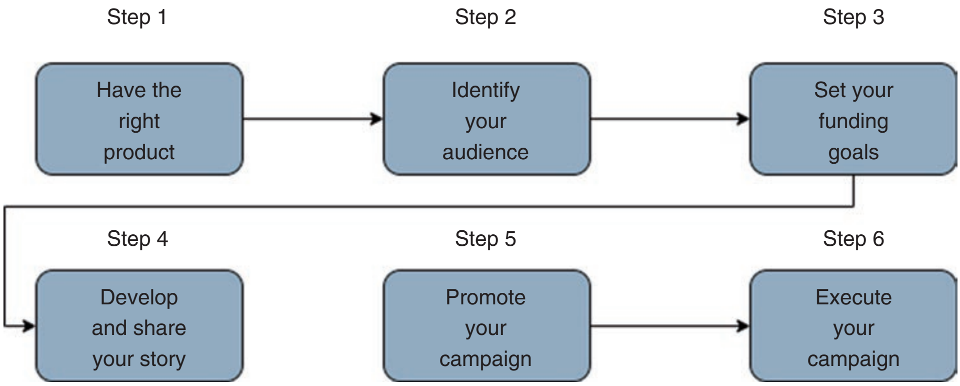


Fig. 2.36 How to run a successful crowdfunding campaign in six easy steps. (MindSea 2021)

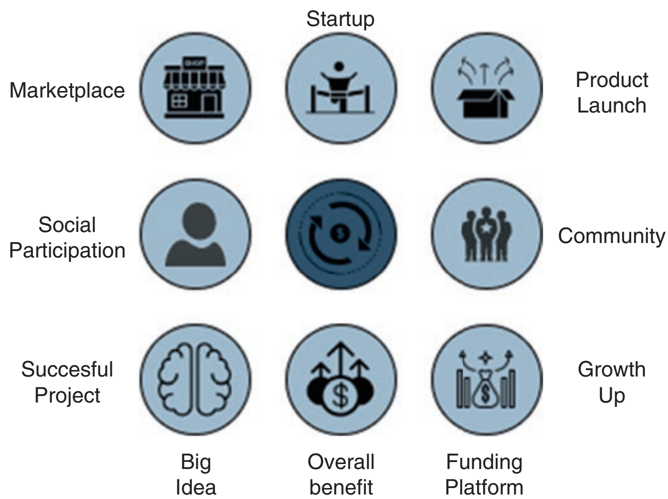


Fig. 2.37 Outline of crowdfunding. (Dashurov 2021)

Table 2.2 User check table for determining whether it is suitable for her/him

	Pre-trading	Pre-profit	Profitable, growing business	Established and steadily growing	Established stable business	Launching new product/service/brand	Making acquisitions
Equity crowdfunding	No	Yes	Yes	Yes	Yes	Yes	No
Rewards-based crowdfunding	Yes	Yes	No	No	No	Yes	No
Peer-to-peer lending	No	No	Yes	Yes	Yes	Yes	Yes

European Commission (2021)

Equity and debt investments' funding are risky investments, but the investor can diversify their capital in a wide range of ways. Individuals can directly support the companies they feel connected to by crowdfunding investment infrastructure (Chen 2021). In the path of developing a project or launching a business, having access to capital is crucial even if the project has nothing to do with R&D. In emerging technologies' case, with the additional necessity to be possessed of enough material to research and develop truly, crowdfunding becomes even more than a way out. Funding by investors and VCs is not an easy method, especially when the project is not finan-

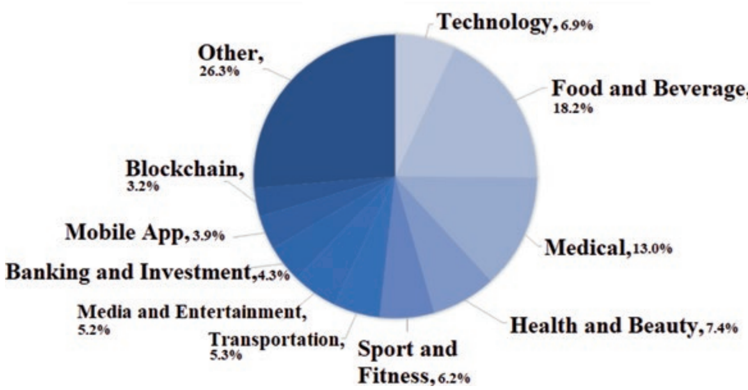


Fig. 2.38 Crowdfunding industries. (Okhrimenko 2020)

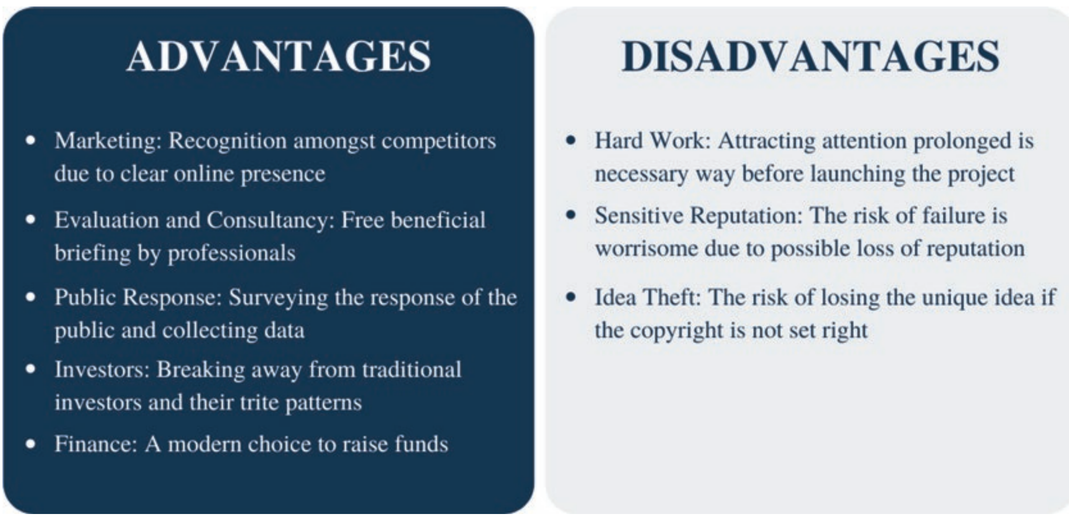


Fig. 2.39 Advantages and disadvantages of crowdfunding. (nibusinessinfo.co.uk 2021)

cially beneficial right away. Crowdfunding is a functional solution to this very problem. Surely, this does not mean crowdfunding does not have its criteria or standards to evaluate within but means that its broad spectrum of funders enlarges the criteria extent. Figure 2.39 summarises several prominent benefits and drawbacks of crowdfunding.

Started by a British rock band in 1997, crowdfunding has become a multibillion-dollar business in less than two decades for artists, filmmakers, organisations, people and now companies. The World Bank report predicts worldwide crowdfunding investments to reach 93 billion dollars by 2025 (Fridman 2016). Although the first crowdfunding portal, ArtistShare, launched in 2000, it is expected that there will be a return to specialised platforms in future years (Fridman 2016). With so many crowdfunding choices, platforms will see value in narrowing their emphasis and attracting a specialised audience. Niches such as gaming, education, music, charities, researchers and local initiatives are creating their platforms to better serve supporters and make themselves noticeable. Rewards-based platforms such as Indiegogo and Kickstarter have garnered a lot of attention in the USA. Equity crowdfunding was the next great wave that began in 2016. Titles III and IV of the JOBS Act have made it feasible for unaccredited (i.e. not wealthy) investors to readily purchase ownership shares in new firms they care about (Fridman 2016). Investing in a start-up's shares was once restricted to rich people. Because of the new rules, businesses are trying to attract investors as well as people who wish to back a company's concept or a goal. Crowdfunding provides firms with a different option for obtaining cash than venture capital or angel investors. The new investment class, a bigger group, made up of Middle Americans, will be the driving force behind investing and hence decision-making (Fridman 2016).

2.15 Cybersecurity

Humankind has been faced with crimes since its existence. The phenomenon of crime, which has developed and changed over the years, has been defined and posted in tonnes of different ways. When it is asked, most people define crime as acts that break the law. The Declaration of Human Rights (1948, art.3) states that "Everyone has the right to life, liberty and security of person". Therefore, in international laws, people have the right to defend their security. The twenty-first century has brought an era with the digitalisation trend to the new danger that humankind requires to defend themselves against. This new threat, which is encountered in all areas of life and whose importance increases day by day, is cybercrime. Various governments and companies are taking many measures to prevent these cybercrimes. Aside from the variety of measures, cybersecurity is still a huge concern for many. Cybersecurity is the practice of protecting systems, networks and programs from digital attacks. Cyber resilience, on the other hand, is the measure of an individual's or enterprise's ability to continue working as normal while it attempts to identify, protect, detect, respond and recover from threats against its data and information technology infrastructure.

This section mainly focuses on the challenges faced by cybersecurity on the latest technologies. It also focuses on the latest developments in cybersecurity techniques, ethics and the future of cybersecurity. For clarity, the cybersecurity concept will be examined in subsets. These subsets include types of attacks, types of cybersecurity threats and sectoral risk management. These will be examined as defence mechanisms against these cybercrime types that endanger individuals and organisations. Nowadays, with the increasing impact of technology in people's lives, the security of information is exceedingly important. Cybersecurity plays an important role in the field of information technology. Information security has become one of the biggest challenges of our time. That is why one of the most valuable things is knowledge of cybersecurity. With the increasing use of technology, a large amount of digital information emerges individually and institutionally. The protection of digital information requires just as much importance. Multiple cyber methods compromise digital information. In the continuation of the chapter, these vulnerabilities and methods that endanger cybersecurity will be examined, and which systems are at risk and what this developing technology promises will be mentioned. Cyberspace can be defined as a worldwide territory in the data ecosystem, the interconnected IT infrastructures including the Internet, telecommunication systems, computer networks and embedded processors and controllers (Committee on National Security Systems (CNSS) 2015).

It is seen in Fig. 2.40; various motivations lead the attackers, from personal gain to drawing attention to social problems. To receive social admiration, cybercrimes might cause many problems by taking large masses behind them. There are many attacks and types of attacks in cyberspace that will require cybersecurity experts to protect their computers. The most known attack types are backdoor, phishing, social engineering and malware.

(i) *Backdoor*

In cybersecurity, a backdoor refers to any approach that enables authorised and unauthorised users to overcome ordinary safeguards and obtain access to high levels through a computer, a network or a software program. Backdoor attacks are a form of adversarial attacks on deep networks. The attacker provides poisoned data to the

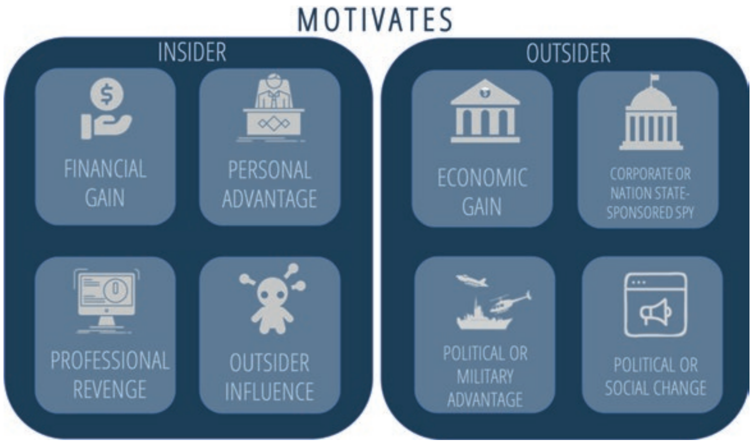


Fig. 2.40 Attackers' motivation

victim to train the model and then activates the attack by showing a specific small trigger pattern at the test time. Most state-of-the-art backdoor attacks either provide mislabelled poisoning data that is possible to identify by visual inspection, reveal the trigger in the poisoned data or use noise to hide the trigger (Saha et al. 2020). When cyber thieves are in the system, personal and financial information can be stolen; other software and hijack equipment can be installed.

(ii) *Phishing*

Phishing is a scam to share confidential info, such as passwords and credit card details. Victims get a harmful email or text message that is like a workman, a bank or a government agency, imitating a person or institution they trust. If the user clicks the bait, a legally valid website counterfeit will be provided. Suppose people enter their username and password to log in. In that case, the attacker who uses it to steal identity sees this information and can thus trade their bank balances and black-market personal information. At this point, different methods are recommended to users and service providers to protect themselves from phishing attacks. The NCSC (National Cybersecurity Center) recommends an innovative layered method called the 4-layer approach for large institutions and cybersecurity professionals ("Small Business Guide" 2018; "Phishing attacks" 2018). According to the research, financial institutions are the target of phishing attacks, as seen in Fig. 2.41, in the first quarter of 2021, followed by social media and SaaS/webmail. Due to increased digital banking transactions during the pandemic period, business e-mail compromise (BEC) is even more costly (APWG 2021).

(iii) *Social Engineering*

In computer science, social engineering relates to the tactics used by thieves to get the victims to do a kind of dubious measure that usually involves security breaches, money sent out or private information. As it is colloquially known, social engineering hacks human behaviour and influences the modelling of societies in a devious way. Social media has produced a culture where sharing everything about everyone is normal and even encouraged by some (Hadnagy 2018). If it is said that cyber thieves hack people's systems using malware and viruses, social engineering is just the same by doing it with people's thoughts. On the other hand, social engineering could be done with information shared online by users themselves. As the Cambridge Analytica case has demonstrated that standard privacy laws may not be enough to safeguard customer data, another branch of the privacy protection debate may be worth investigating (Sun 2020). Victims who solved the quizzes gave their personal data and information to the harmful social engineering companies. Emotions that can be utilised are love (in its various forms), hate or anger (us versus

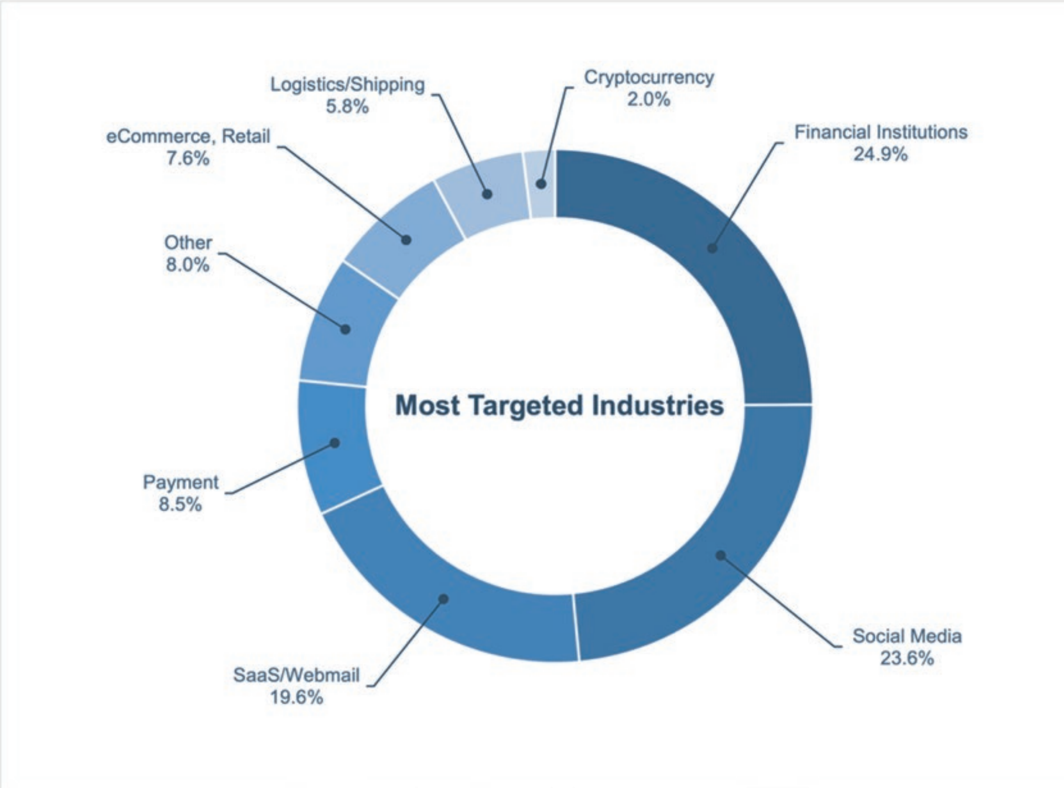


Fig. 2.41 Most targeted industries

them), pride (in themselves or their organisation) and futility (in themselves or their organisation) (there is no other option). Picking the correct emotion is simpler in person because we can read body language or via phone to assess the tone of voice and alter the approach based on the scenario. This approach aims to influence the target's emotions so that they overcome their natural cognitive replies (Winterfeld and Andress 2013). Then by researching and analysing the flip side of this coin, US elections were affected in a roundabout way by this kind of harmful social engineering by social media companies.

(iv) *Malware*

Malware is an inclusive word describing any malicious software or code damaging to computers. Malware has become a significant tool for unlawful economic activity, and its developers go to great lengths to avoid detection by anti-malware programs (Rieck et al. 2008). Malicious software (malware), hostile, intruder and purposely bland seeks the use of computers, computer networks, tabling and mobile devices to enter, harm or disable, frequently gaining partial control of activities of a device. It interrupts regular operations, like copying, encrypting, destroying or modifying essential computer functions without knowledge or permission and monitors computer activities. Commonly encountered types of malware are viruses, keyloggers, worms/trojans and ransomware. This type of malware is placed on your devices by attackers to threaten users. Except for the ransomware attacks, most types of cyberattacks aim to convey data/information to the attackers, but the ransomware attacks are more complicated. The attacker encrypts the data with his attack and demands a ransom from the victim. In such cases, the crucial point is that when the attacker gets what he wants, he can access and damage the information in the system again since he has encrypted software in the system. This type of malware is placed on your devices by attackers to threaten users by spying on users' personal data. Spyware, malicious software, regularly collects data from targeted victims' devices. Spyware, *Pegasus*, caused a major international scandal. As data from Forbidden Stories collaboration with Amnesty Security Laboratory states, approximately 180 journalists were affected by this spyware (Rueckert 2021).

Unlike companies, individual users could lose their data in unfortunate situations because of cybercriminals. On the other hand, this threat can cost the data of numerous users. Therefore, companies may lose their reputation and reliability. Companies should care about cybersecurity as a corporate culture to prevent these threats and attacks from outside. Creating a cybersecurity culture requires altering how everyone works, how leadership is involved, how processes are implemented and how challenges are addressed. At the core of a culture of cybersecurity, each employee can carry out their daily tasks in the most secure way imaginable. To create this culture, companies need to take some external and internal actions. There are some influencing factors such as external regulations, national and social cybersecurity culture. Another factor affecting this culture in the company are activities such as managerial communication plans, training and performance measurements. In this way, values and beliefs will change in terms of both the individual and the group, and a cultural environment on cybersecurity will be created. As these beliefs become established, new behaviours will emerge that are both work-related and company-related.

A. *Systems at Risk*

(a) *Utilities and Industrial Equipment*

Computerised systems provide many services such as opening-closing valves in electricity networks, nuclear power plants, water, gas and treatment plants. Even when devices are not connected to the Internet, they can be vulnerable and potentially under attack. Devices that are not connected to the Internet are threatened by a worm called Stuxnet. Great damage can be done by individuals and nations. National goals in cyberattacks might include harvesting information, reducing the target nation's war-making capabilities, threatening other nations by showing their capability making the target nation feel weak and demoralised and/or creating a national distraction in the target nation. Since no one is directly killed in a cyberattack on the power grid, nations have been willing to conduct them without a declaration of war (Ahern 2017).

(b) *Aviation*

As in many sectors, the aviation sector works with complex systems. For this reason, everywhere, from airports to cockpits, is at the risk of cyberattacks. Interconnectivity of systems and dependency on technology created the optimum premises for new risks to emerge. The aviation industry uses a wide computer-based interconnected system, spanning from air navigation systems, onboard aircraft control and communication systems, airport ground systems, flight information systems, security screening and others used daily and for all aviation-related operations. The trend of the aviation industry is to become increasingly digitised. Digitalisation brings along new hazards as the interactions between people and systems make the risk harder to predict (Civil Aviation Cybersecurity 2021).

(c) *Consumer Devices*

In the past decade, with technological developments, people started to frequently use everyday devices such as smartphones, tablets, smartwatches, e-readers, etc. in their daily lives. Although personal computers and laptops have existed in our lives for a long time, the number of devices that can connect to the Internet has increased with more recent technologies. These kinds of daily use devices are commonly vulnerable to the threat of cyberattacks.

(d) *Large-Scale Corporations*

Large-scale corporations have always been the biggest targets of cybercrime. The crime incidents collect information such as financial, registered credit card, demographics, or address information, and then this information is sold in environments such as the deep web in exchange for money. In addition, attacks on large companies are not only aimed at financial gain but also to harm companies, damage or embarrass their brand image.

(e) *Autonomous Vehicles*

Vehicles are increasingly computerised. For example, almost every part of a car, from the complex engine to the door handle, now contains electronic circuits. Door locks, cruise controls and many vehicles use mobile phone networks, Bluetooth and Wi-Fi. Recently, with the increase in driverless and electric vehicles, new cyber risks have emerged. There are many ways to initiate an AV cyberattack. An attack can target the software that manages visual information and road infrastructure, or it could be a physical attack on the vehicle's hardware (Alves de Lima and Correa Victorino 2016). There are many risks, such as brake-accelerator pedals, door locks and motors out of the driver's control. Even driverless vehicles receive software updates over the Internet and require many security policies.

(f) *Governmental Institutions*

Activists attack the state system, military, police and intelligence systems. Public institutions have become potential targets as they are now digitised. Compliance with various safety certifications and quality systems is required.

(g) *Internet of Things and Physical Vulnerabilities*

The Internet of things, or IoT, is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction (Gillis 2020a, b). One of the biggest concerns in the spread of IoT devices and technologies is the security problem. People are worried about undesired control of technological devices in all areas of life, and even more, personal and unconventional devices such as IoT are afraid of being controlled by unwanted people. In the future, although IoT devices are an indispensable part of life, they will be exposed to more cyber threats.

B. *Protection*

(a) *Attacker Types, Motivations and Gains*

Cyberattacks are becoming more common day by day. The main reason for this is that cyberattacks provide a lot of benefits to attackers. Cyberattacks are categorised according to where the attack came from. Threats may occur in the internal or external sources. Internal attacks could be more harmful because the attacker has been directly accessing the users' information.

(b) *Computer Protection (Countermeasures)*

Raban and Hauptman (2018) indicate that some measurements and protections enable threats to be absorbed and recovered and company activities restored to normality quickly. It involves several strategies, such as adaptive reaction, variety, redundancy, disappointment and proactive resistance. In recent decades, computer and network innovation have quickly developed and have been used rapidly in different areas, bringing enormous effects on human civilisation and promoting the economy, society, science and engineering of society as a whole considerably (Chunli and DongHui 2012). Computer technology and network technology are utilised in current civilisation and are still continually deepened in many aspects of culture. The article now suggests the suitable methods and technological solutions that may rapidly develop in computer networks to address the abovementioned security concerns:

(c) *Control Security of Password and Authentication and Authorisation*

The organisational leaders should regularly identify an information security weakness to help them identify all sorts of variables and diversity of safety security issues to detect and process any flaws in a timely manner to rectify any security flaws and verify the results immediately. The identification of weakness generally involves the scan of the network's security, data security scan and the scan of the database server.

(d) *Applying Firewalls*

A firewall is a computer system application that enables people to filter attackers, viruses and malware which try to enter the Internet on the computer (Reddy and Reddy 2014). Any received data via the firewall must be tested to see if to accept, refuse or divert, verify and regulate all inbound and outbound network services and visitors, assure data protection and safeguard the computer networks as far as possible against malicious assaults. As a result, the growing complexity, openness of the network, complicates the issue of security. Also, it demands the development of advanced security technologies in the interface of between varieties of networks for security domains, for instance, Intranet, Internet and Extranet (Abie 2000).

(e) *Data Authentication and Encryption*

The data security contained in the database can be assured by encoding some critical data. After encrypting, do not be concerned about the loss of data even when the existing network is destroyed. The files received must be authentically verified before download if they came from a trustworthy and dependable provider and are not modified.

(f) *Computer Users and Managerial Sensitivity Upgrading Training*

Individual Internet users select separate passwords, data to apply for legal operations, keep other users from illegal network connectivity and use cybersecurity sources for network security training following their duties and authority. At the same time, the usage of antivirus software updates, which are the front end of the network, should be considered when the virus strengthening is in use. Improve information security awareness management, employment morals, sense of commitment development, build, perfect safety management system, steadily strengthen computer system network security centralisation management, enhance information system safety build, security and provide a reliable guarantee.

The market growth of cybersecurity is quite vivid as there is a growing concern for security and cyber resilience in enterprises. Figure 2.42 shows the market share in cybersecurity applications in 2020 and 2021.

2.16 Data Hubs

Data hubs are structures that store, analyse, classify and organise the data obtained from various sources as a central model while maintaining the hierarchical structure of the data and providing access to all partners to the content (Küfeoglu and Üçler 2021). Data hubs can also be defined as a solution that utilises different technologies. These technologies are data warehouses and data science (Christianlauer 2021). By integrating a system or component with a data centre over data hubs, all data related to this system or component is shared. Data can be easily transformed and distributed to various cloud data warehouses and various business intelligence (BI) tools thanks to data hubs (Choudhuri 2019).

Many businesses are looking at numerous options on the market to develop their data hubs to handle their core vital company data, and data hubs are becoming more popular. However, this technology is commonly misunderstood as a substitute for data warehouses or data lakes. Data hubs serve as hubs of intermediation and data interchange, whereas data warehouses (DWH) and data lakes are thought to be endpoints for data collecting that exist to assist an organisation's analytics. A summary of each solution's

Market Segment	2020	2021	Growth (%)
Application Security	3,333	3,738	12.2%
Cloud Security	595	841	41.3%
Data Security	2,981	3,505	17.6%
Identity Access Management	12,036	13,917	15.6%
Infrastructure Protection	20,462	23,903	16.8%
Integrated Risk Management	4,859	5,473	12.6%
Network Security Equipment	15,626	17,020	8.9%
Other Information Security Software	2,306	2,527	9.6%
Security Services	65,070	72,497	11.4%
Consumer Security Software	6,507	6,990	7.4%
Total	**133,775**	**150,411**	**12.4%**

Fig. 2.42 Growth of market segments (in USD)

properties can be seen in Fig. 2.43 (Christianlauer 2021).

Data permanence is only one aspect of a modern data hub. The goal of previous data hub generations was to centralise data into a single location and store it for a limited number of sectoral use cases. Today's data hubs must fulfil a growing variety of operational and analytical use cases and centralise data. Some characteristics of a modern data hub are listed below.

1. A modernised data hub is not a permanent platform. On the other hand, the modernised data hub is a virtual or physical gateway through which data flows.
2. Data is represented in a modernised data hub without being physically persistent.
3. A modernised data hub has a corporate scope, even in today's complicated, multiplatform and hybrid data landscapes.
4. Modernised data hubs differ significantly from traditional ones. A single data domain or use case is limited in most traditional hubs, such as a customer master or a staging area for incoming transactions. Typically, a modernised hub is multi-tenant, serving many business units and including all data domains and use cases.
5. A modernised data hub isn't the same thing as a silo. A hub cannot be a silo if it integrates data widely, provides physical and virtual viewpoints, reflects all data regardless of physical location and is properly governed. A contemporary data hub with these capabilities is an antidote to silos (Russom 2019).

A data hub collects information from a variety of sources, including data warehouses, data lakes, operational datastores, SaaS applications and streaming data sources. One or more business apps can access the information in the hub. For years, data hubs have been used in applications like master data management which aggregates consumer data from several systems to detect missing data and correct inconsistencies and errors across all data sources (Ivanov 2020). The enterprise data hub (EDH) is a solution to big data challenges. EDH is a data management solution that includes storage, processing and analytics applications for both new and old use cases. New open-source technologies, machine learning (ML), artificial intelligence (AI) and cloud-based

	DATAHUB	DWH	DATA LAKE
STORAGE OF DATA	YES	YES	YES
INDEX	YES	YES	NO
LATENCY OF DATA	SMALLER	BIGGER	SMALLER
ALL KINDS OF DATA	YES	NO	YES
INNATE ANALYTICS	YES	NO	YES
MACHINE LEARNING OPTIMIZED	YES	NO	YES

Fig. 2.43 The properties of data hub, DWH and data lake. (Christianlauer 2021)

architectures all necessitate a flexible EDH that offers faster data access and cheaper costs than traditional data storage systems. The partnership between business and information technology (IT) to create an EDH will result in a faster time to market, more product variety and more profits (Mukherjee et al. 2021).

A data hub is a contemporary, data-centric storage infrastructure that enables enterprises to aggregate and exchange data to fuel analytics and AI applications (PURESTORAGE 2021). Although it is a technology, this is an approach to arbitrate more effectively, share, connect and/or determine where, when and for whom target data should be sustained. Endpoints, which might be programs, processes, people or algorithms, interact with the hub in real-time to send or receive data from it (Lauer 2021).

A data hub sets up a connection to each system or component that needs to be integrated and ensures that the connection is shared with all other systems that must interact. Data services can be exposed and posted consistently, allowing for better integration of system-wide data and the need for data replication to support business processes between systems. For example, any change made by anyone to their credentials takes place within this data hub, and all subscription applications can continue to use the connection. The data hub simplifies data governance requirements by keeping data in a central location. Data can be easily transformed and distributed to other endpoints such as cloud data warehouses and analytic BI engines (Choudhuri 2019).

A data hub provides an opportunity for data custodians and data users to collaborate on determining whether data is critical for distribution to the user community. This is a paradigm change from data warehousing systems where data custodians made all decisions about which data was made available to consumers. These benefit both parties in this equation: Data custodians may focus their resources on what is recognised as having the most demand/need while collecting input on datasets' quality and usefulness. Data consumers can thus obtain more data and spend less time negotiating access to datasets maintained within organisations. With these aims in mind, a data hub is for people as much as it is for data (Delaney and Pettit 2014).

Master data management (MDM) focuses on mastering collections of business data based on programmed (hard-coded) rules to enforce preset rules and synchronise (bi-directional) operational systems on one set of "golden rules" thanks to its well-documented definition and purpose. This was a much-needed guideline for data management and governance activities. Many businesses, however, have failed to implement MDM initiatives due to their complexity and cost, as well as the hazardous and ambitious nature of attaining the objective of having a single, agreed-upon set of data semantics provided across the organisation (Semarchy 2021). It is quite difficult to form a clear idea with the available data from organisations running multiple and independent systems (Precisely Editor 2021). Simultaneously, data analytics require mastered data and lineage to establish a data hub with accurate data attributions. As a result, analytics-driven companies began to migrate away from operational system connections and towards smaller, localised data hubs with agreed-upon analytics and application semantics. This is not to suggest that MDM is no longer necessary; rather, it demonstrates how businesses understood they needed to be more capable, flexible and nimble. It is noted in this context that there are a variety of scenarios linked to the utilisation of data hubs (Semarchy 2021). Data hubs have been developed as a solution in the presence of complex and constantly updated data sources, in cases where they actively benefit from the data at hand, when real-time and operational data are desired to be used in contrast to past snapshots within the enterprise, and a reliable integration system is needed (Marklogic 2021). Figure 2.44 represents the type of communication between multiple peers and the data exchange structure of business before the data hub (Küfeoğlu and Üçler 2021).

The benefits of data hubs, both about the mentioned scenarios and in general scope, are listed below:

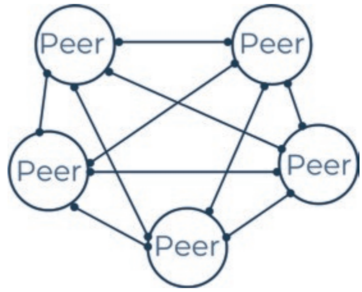


Fig. 2.44 Peer-to-peer data exchange and market structure before data hub. (Küfeoğlu and Üçler 2021)

- Provides visibility to all data.
- Controls data consumption, ownership and sharing from a single location.
- Demands complex qualities that cannot be developed on their own.
- High-performance data pipelining moves data at the optimum latency.
- Provides data operations with fine-grained control via rules and processes.
- Creates a linked architecture out of what would otherwise be a collection of silos (Russom 2019).

Due to the scenarios mentioned above and the various benefits it offers, data hub technology emerges as a solution that can help to easily overcome many difficulties that may arise in various operational processes and help the emergence of technology-supported business processes that users need (Choudhuri 2019). Figure 2.45 demonstrates the market communication system after the establishment of the data hub (Küfeoğlu and Üçler 2021).

A data hub is a digital environment that allows business and data teams to share data and access and deliver rich data services highly secure. It provides the flexibility and worldliness required for designing and developing unique use cases (Dawex 2021). Considering the future of data hubs, one of the most important issues in business life, "marketing", cannot be overlooked. Data hubs are the next step in the marketing stacks'

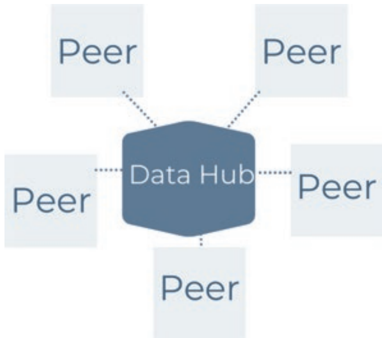


Fig. 2.45 Peer-to-peer data exchange and market structure after data hub. (Küfeoglu and Üçler 2021)

development, and they're likely to become more popular in the future. The hub idea is essential because it can assist intelligently in organising campaigns across the digital and physical domains and because a data hub serves as an information aggregator rather than another marketing solution. The main distinction between a data hub and a marketing stack is that data hubs are completely back-end solutions that allow for cross-channel insights without being limited to a certain set of solutions. As a result, it is predicted that data hub utilisation would increase over time. More data involvement every day in marketing, such as cross-channel editing and real-time personalisation, may provide significant long-term effects. The data hub is a central location where consistent, tailored messages may be provided through a single interface via email, online domains, display advertisements and mobile applications and then tracked as part of the decision-making process. Companies that capture this future are likely to succeed where others falter (Zisk 2016). Marketing operations that work successfully create, sustain and expand demand for goods and services in society (Chand 2021). Considering the importance of marketing activities in economic development, data hub technology, which is one of the marketing strategies, contributes to the economy.

2.17 Digital Twins

Digital twins have become more popular with the Internet of Things (IoT) technologies which enable monitoring physical twins in real-time at high spatial resolutions. The monitoring process takes place by using both miniature devices and remote sensing that produce ever-growing data streams (Pylianidis et al. 2021). The main goal of the digital twin is to create highly accurate virtual models of every physical entity of the original model to mimic their states and behaviours for further optimisation, evaluation and prediction (Semeraro et al. 2021). Before the industrial revolution, artisans primarily made physical artefacts, resulting in one-of-a-kind examples of a given template. However, when the notion of interchangeable components was introduced in the eighteenth century, the way things were designed and made changed dramatically as firms mass-produced products' replicas. The mass customisation paradigm has recently emerged, which attempts to combine these two well-established manufacturing techniques to attain low unit costs for personalised items. Even though such paradigms of manufacturing allow for the mass production of vast amounts of comparable, i.e. tailored components or products, the created instances are not duplicates that are related. On the other hand, building a twin is creating a duplicate of a component or a product and using the duplicate to consider various other conditions of the same component or product, therefore building a relationship between various copies. This concept is believed to have come from NASA's Apollo program, when "at least two identical space vehicles were created to allow mirroring of the space vehicle's circumstances during the trip" (Rosen et al. 2015). While the terminology has evolved since its beginning in 2002, the underlying principle of the digital twin model has stayed relatively constant. It is mainly linked to the idea that the creation of a digital informational construct of a physical system can be independent of that particular physical system. This digital information then could be a "twin" of the information that belongs to the initial physical system and would be connected to the original system itself during the system's lifespan. The basic working principle of digital twin technology is shown in Fig. 2.46.

The term digital twin dates back to 2002 when the University of Michigan held a presentation

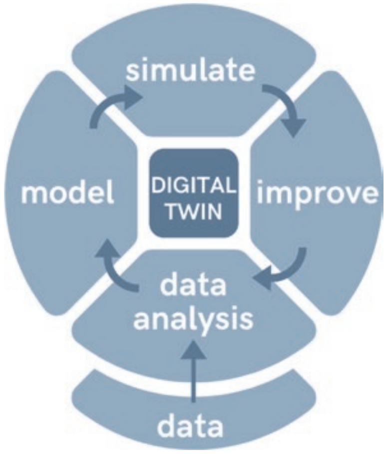


Fig. 2.46 Basic working principle of a digital twin

for the industry about the formation of a product life cycle management (PLM) centre. The presentation's slide in which the digital twin was introduced, shown in Fig. 2.47, was called "Conceptual Ideal for PLM". The slide included all the components of the digital twin, such as real space, virtual space, the link for information flow from virtual space, the link for data flow from real space to virtual space and virtual subspaces. The model's proposition was composed of two different systems. The first system was about the physical system that has always existed. The second one was a new virtual system that held all the information and conditions about the physical system. This meant that the real spaces were mirrored to its virtual space model or vice versa. The term PLM, or product life cycle management, indicated that it was not a static representation but rather the two systems would be linked over the system's lifespan. As the system moves through the four phases of creation, production, operation and disposal, the virtual and the real systems are linked together to create a more efficient way of working (Grieves and Vickers 2017).

The rise of the Internet has permitted the creation of more complex virtual models of various physical objects and the integration of such models into systems engineering during the last few decades. These models are utilised as the master product model, which includes the model-based description of needed product features and design verification and validation. The advancement of "microchip, sensor and IT technologies" cleared the path for the creation of smart products that track and transmit their operational conditions, allowing them to contribute data regarding their status into their product models. Advanced sensing procedures, which go beyond mathematics and scanning, enable the collection of huge quantities of data from physical objects in a simple, fast and reliable manner. The significant advancements in simulation technology, along with the expanding capabilities for obtaining and transmitting data from goods, allowed virtual twins of actual products to be created. As a result, the current concept of the "digital twin" idea has emerged (Schleich et al. 2017). Some general questions and answers about the digital twin are listed in Table 2.3.

Digital twin technology helps us to see how efficient and effective the system is in the operations and support/sustainment phase. Moreover, by using digital twin technology, companies can prevent undesirable behaviours, both predicted and unpredicted, to avoid the costs of unanticipated "normal accidents". In addition, by using a digital twin, we can significantly reduce the cost of loss of life by testing more conditions that a system can face in a real-world environment (Grieves and Vickers 2017). As the manufacturing process steps become more digitised, new potential for increased productivity emerges. Additionally, as the number of applications for digital twins grows, the cost of storage and computing decreases (Parrott and Warshaw 2017). Today, the technology exists to construct the foundations of a digital twin to aid in the care and management of people with various chronic illnesses. The next step is for forward-thinking companies and institutions with high-quality technologies and high expertise in subject matter to begin field testing such systems in real-world settings, to assess the impact of the constantly improving design on engagement, health outcomes and service utilisation (Schwartz et al. 2020).

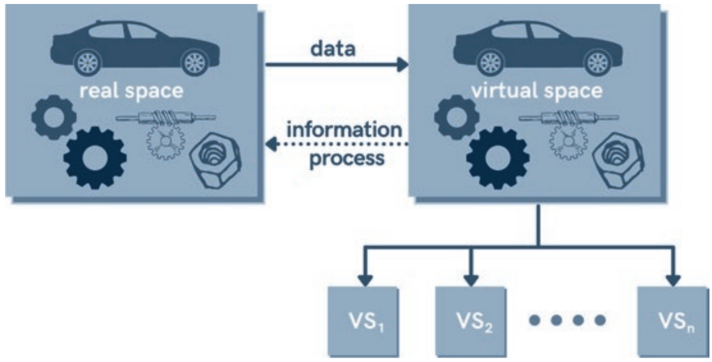


Fig. 2.47 Conceptual ideal for PLM. (Grieves and Vickers 2017)

Table 2.3 Questions and answers on digital twins

Question	Answer	
What is a digital twin?	A collection of processes that simulate the behaviour of a physical system in a virtual system that receives real-time input to update itself throughout its lifespan.	
	The digital twin duplicates the physical system to detect failures and modify opportunities, suggest real-time measures for optimising unpredictable situations and monitor and evaluate the operational profile system.	
Where is the digital twin used?	• Healthcare	• City management
	• Maritime and shipping	• Aerospace
	• Manufacturing	• AR/VR
Why should a digital twin be used?	Digital twins can help businesses enhance their data-driven decision-making processes substantially. Businesses utilise digital twins to evaluate the capabilities of physical assets, adapt to changes, enhance operations and add value to systems by connecting them to their real-world versions at the edge.	
Who is doing digital twins?	• Microsoft azure	• Akselos
	• Ansys twin builder	• GE Predix
	• Siemens PLM	• Aveva

The reasons for using "digital twins" to achieve business goals can be gathered around five headings as (Arnautova 2020):

1. *Risk Evaluation and Manufacturing Time Are Both Accelerated*

Companies may test and evaluate a product through digital twin technology before the product comes into existence in the real world. It allows engineers to realise process-related problems before manufacturing through duplication of the intended production process. Engineers can disrupt the system to create unexpected circumstances, analyse the response of the system and come up with mitigation methods. This new capacity improves risk assessment, speeds up the creation of new goods and increases the dependability of the manufacturing line.

2. *Accurate Predictive Maintenances*

Businesses may examine their data to detect proactively any faults inside the system because a digital twin system's IoT sensors create large data in real time. This capability enables organisations to facilitate more precise predictive maintenance, which leads to an increase in production line efficiency and a decrease in costs of maintenance.

3. *Synchronised Monitoring Remotely*

Getting a real-time, detailed perspective of a huge physical system is typically challenging, if not unachievable. On the other hand, a digital twin may be accessed from anywhere, allowing users to monitor and adjust the system's performance remotely.

4. *Enhanced Association*

The automation of processes and reach to system information 24 hours a day, 7 days a week enables technicians to get deeper into communication between teams, resulting in increased productivity and operational efficiency.

5. *Making Profitable Financial Choices*

The cost of materials and labour, which are grouped and called financial data, can be integrated into a virtual depiction of a real-world object. Businesses may make more accurate and fast decisions on whether or not changes to a manufacturing value chain are financially viable, thanks to the availability of a vast amount of real-time data and powerful analytics.

A digital twin consists of a user interface, monitoring and analytics components. The components that are mentioned are the initial stage in enabling a digital twin to monitor, analyse and evaluate agricultural systems while also providing a continuous stream of operations. A more complex version of a digital twin could include actuator parts to control fans and windows in a greenhouse. If needed, the monitoring and control operations would be performed constantly and can report relevant information to different stakeholders. The more improved digital twin model needs simulation components to decide based on past and future predicted conditions of the physical twin (Pylianidis et al. 2021). It may utilise considerably less expensive resources in designing, producing and running systems because information replaces wasted physical resources. It can better comprehend systems' emergent forms and behaviours by modelling and simulating them in virtual space, reducing the accidental errors mainly made by humans (Grieves and Vickers 2017). Future advancements could be expected since computer technologies show no signs of slowing down. Finally, because the digital twin reflects the physical system, we may be able to use the virtual system while the actual system is in use. Capturing and utilising in-use data, as well as system front running, are two possible applications. The digital twin idea has the potential to alter how we think about system design, production and operation as well as minimise the number of UUs (unpredictable and undesirable circumstances) in complex systems and supplement systems engineering (Grieves and Vickers 2017).

2.18 Distributed Computing

Distributed computing is a field of computer systems theory that investigates theoretical concerns relating to the organisation of distributed systems. In a more limited sense, distributed computing is described as the use of distributed systems to tackle time-consuming computational problems. In short, it is the simultaneous solution of various parts of one computational task by several imaging devices (Косяков 2014). DARPA established the first distributed system in the 1960s under the name "ARPANET". Ethernet is the first widespread distributed system that was invented in the 1970s. Although the goal is to program a single piece of hardware to run multiple computers, these computers work as a single system. The aim is to create a network connected with different computers. Figure 2.48 shows how distributed computing works.

Distributed computing is a technique for solving time-consuming computational problems by combining several computers into a parallel computing system (Косяков 2014). Multiple software runs on different computers as a single system affects a distributed computer system. It is possible for the components of the distributed computer system to be either close to each other, connected by a local network, or physically remote, connected by a wide area network. Personal computers and other components such as mainframes, workstations, minicomputers and so forth can be grouped to form a distributed system (IBM 2017).

There are many definitions on this topic, but the most original one belongs to Leslie Lamport. According to him, distributed computing is the name given to the cooperation of two or more machines interacting with each other on the network for a purpose. By machine, it means a wide spectrum ranging from supercomputers or personal computers. By network means close areas such as the same campus or intercontinental, and it has a wide range of machine types. If it is needed to separate and analyse distributed computing in the literal sense, "distributed" means

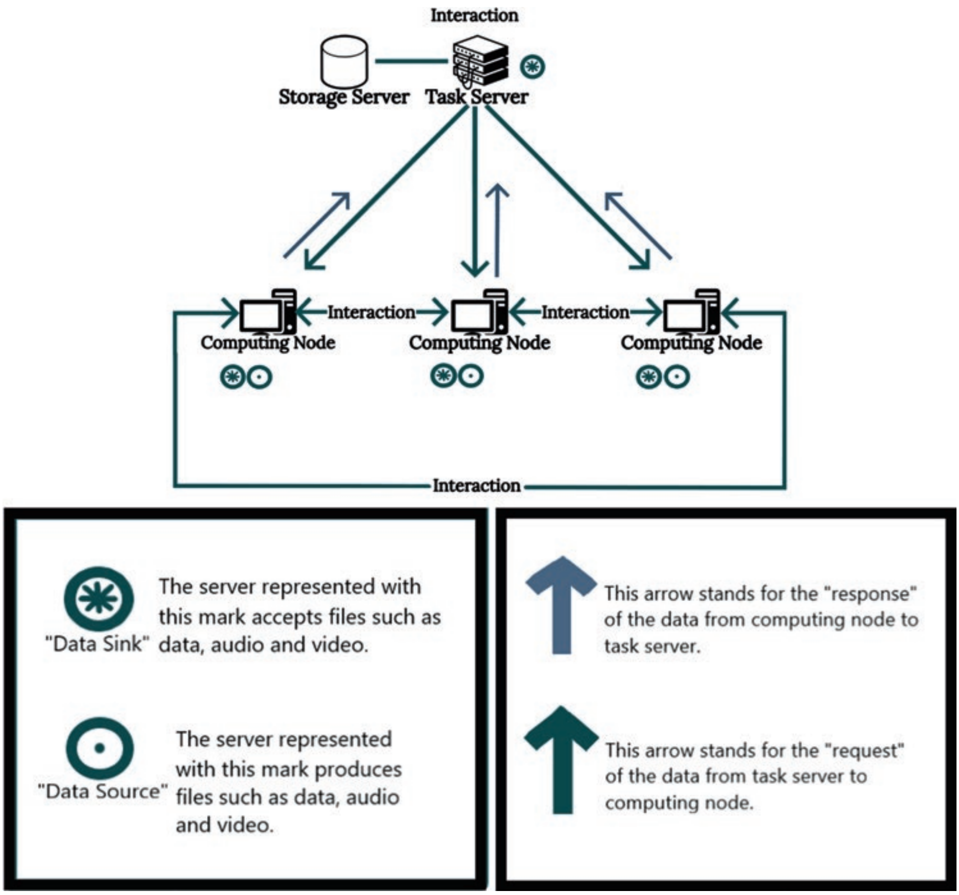


Fig. 2.48 Structure of the distributed computing

spread out in space (Lamport and Lynch 1990). However, well-known Russian professor Andrew S. Tanenbaum defines this system as a set of *independent computers*, which presents the users of the system as a *single* united system. The independent computers by themselves cannot be a single united system. This is possible only if the special programs are used, which is the *middleware* (Косяков 2014). Thus, there is one single system to which connected nodes and all of them together solve a problem. To understand distributed systems and distributed computing, examples of application areas can be seen in Fig. 2.49.

Communication networks called *closely coupled,* and *loosely coupled* are a characterisation factor of the distributed system. The location of the processors relative to each other indicates the communication network; consequently, interprocessor communication's speed and reliability can be roughly defined considering the communication network. Components of the closely coupled network are spatially close to each other, and generally, communication is said to be fast and reliable. On the other hand, a system consisting of physically distant components is called a loosely coupled network where generally reliability and the speed of the communication are less than that of a closely coupled network (Bal et al. 1989).

Also, according to Gibb (2019), distributed computing systems have three characteristic features, the first one works on all parts in the system simultaneously, the second the clock concept is not global and the last one does not affect the other parts in the system when one part fails. The main connecting link of distributed computing

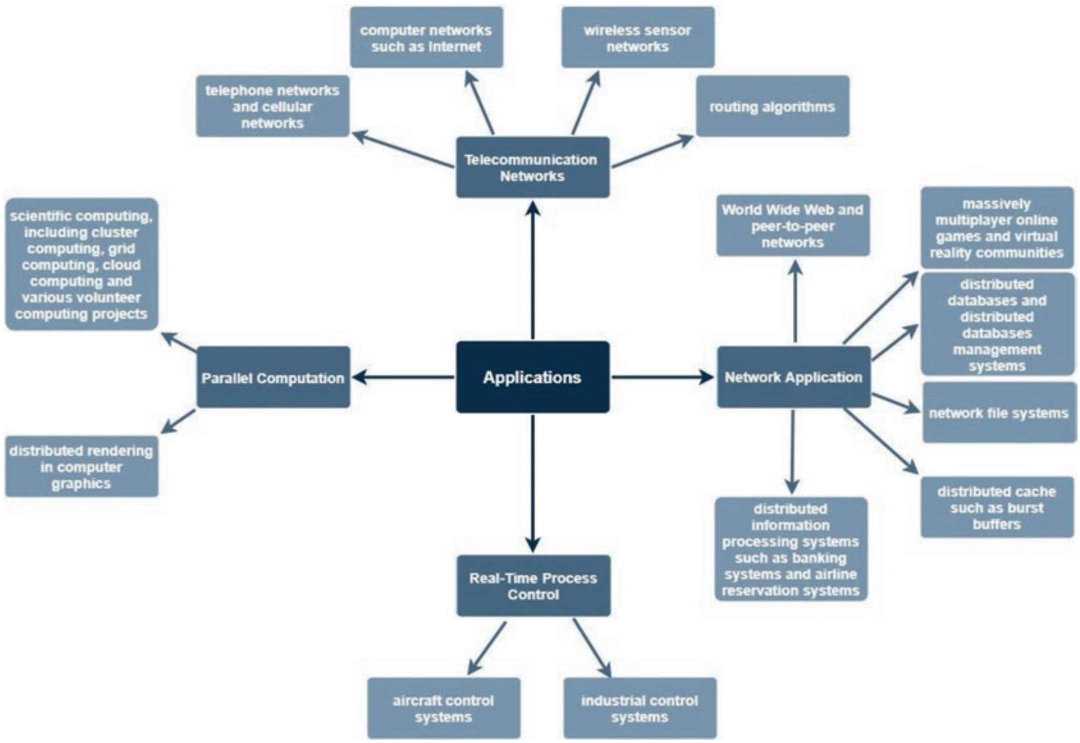


Fig. 2.49 Examples of distributed computing's application areas. (Jahejo 2020)

systems is software. A distributed computing system is a software and hardware system dedicated to solving a certain problem. On the one hand, each computing node is a self-contained unit. The software component of the DCS, on the other hand, should give users visibility into working with a unified computing system. In this way, the DCS is distinguished by the following significant characteristics:

- The ability to work with a variety of devices.
- Including those from diverse vendors.
- Compatible with a variety of OS systems.
- On a variety of different hardware platforms (Г.И. Радченко 2012).

There are several classifications of distributed control systems:

- Resource discovery methods.
- Resource availability.
- Resource interaction approaches.

Many different technologies provide search and discovery of resources in the WAN (e.g. resource discovery services such as DNS, Jini Lookup and UDDI). An example of a centralised resource discovery method is DNS (domain name system). This service works on principles that are extremely like the principle of the phone book (Г.И. Радченко 2012). Also, there are four types of distributed systems (Gibb 2019). These are shown in Fig. 2.50.

We are living in a technology era, and research, explorations, inventions and the development of useful applications are usually done with the help of computers. Because of the abundance of information, the run time of the simulations and the required memory scale-up, we will eventually require computers with high performance and many computation resources to use time efficiently. Therefore, distributed computing has become a trend for high-performance computation for complex applications (Lim et al. 2011). The fact that the organisations that use the programs are scattered is one of the main reasons

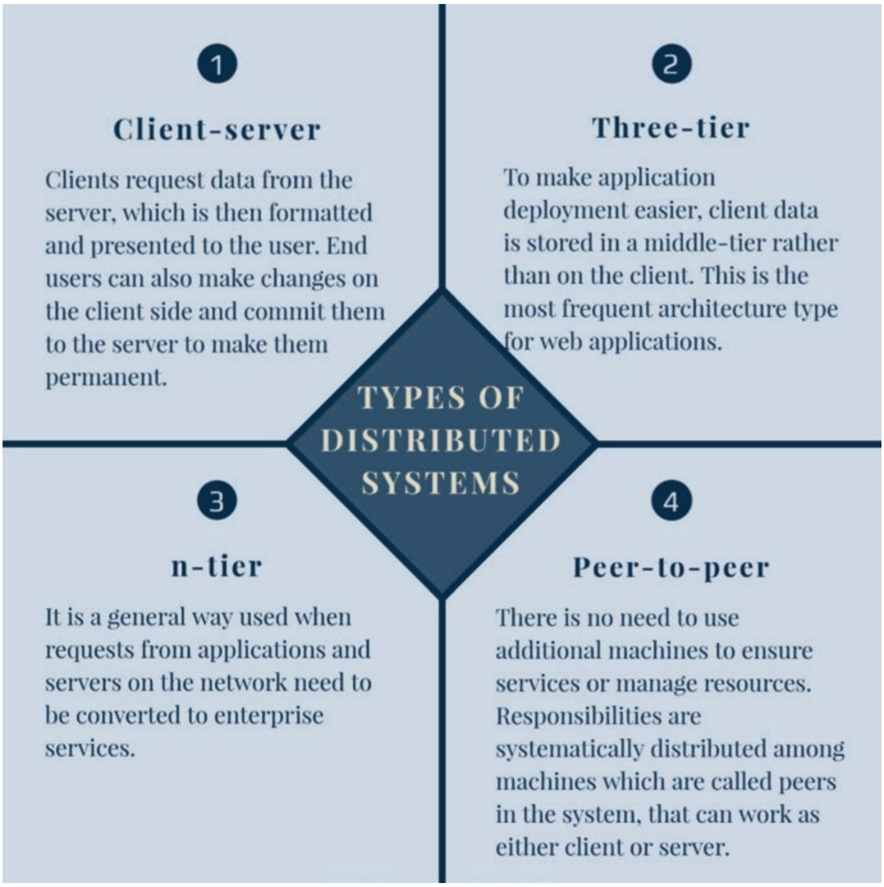


Fig. 2.50 Types of distributed systems. (Gibb 2019)

why distributed programs are useful. A company, for example, is divided into multiple divisions. Each division has its own set of tasks and uses internal data to carry out operations. However, so the divisions supply services to one another, there must be some communication between them. Physically tight divisions or geographically distant divisions are also possible (Liskov 1979). In addition, distributed computing and distributed systems offer many other advantages and useful features for the users. Some of which are listed (Kshemkalyani and Singhal 2007) as follows:

- *Enhanced reliability:* Reliability can be said to be one of the critical features of the distributed system. This is because the corresponding application or simulation can be replicated and checked several times in a distributed structure. Besides, it is quite unlikely for the components of a distributed system to malfunction simultaneously, which ultimately increases reliability.
- *Inherently distributed applications:* A considerable number of applications should be distributed. Particularly for such applications, distributed computing becomes imperative and indispensable.
- *Physically distant data and resource accessibility:* It is often not reasonable to copy all the data to all the components of a distributed system to achieve a distributed computing application because of the sensitivity or capacity of the corresponding data. For example, payroll data of a worldwide company is kept in a common single server accessible by all its branches remotely because of the unsuitability of this

data to be copied in each branch of this company. Furthermore, the data kept in the supercomputers is accessible remotely, although supercomputers are in certain locations. Distributed protocols and middleware, therefore, have gained further emphasis with rapid developments in resource-constrained mobile devices as well as wireless communication technology.
- *Better performance/cost ratio:* The performance/cost ratio is improved with the use of remote accessibility and resource sharing, which is distributing the resources across the system so that they are not overloaded on a single site. Splitting a computation across the components of a distributed system might yield an increased performance/cost ratio compared to utilising parallel devices.
- *Scalability:* The processors in a distributed system are generally connected by a wide-area network. Hence, attaching additional processors to increase capacity and/or performance does not create a direct bottleneck that can affect communication immensely.

Previously, economic concerns supported sharing a single computer among many users, and effort in operating systems was focused on supporting and controlling such sharing. However, there is no longer any need to share a single, costly resource. Processors and memory have become much more affordable thanks to advancements in hardware technology (Liskov 1979). With the rapid development of microprocessors, distributed computing systems have become economically attractive for many computer applications. The calculation is the most important thing in computer science. After this technology, there will be some contribution to other emerging technology areas. For example, datasets grow day by day in every field, requiring more parallelism. So, machine learning algorithms will need more performance and drive skills. Deep learning models are among the highest computational applications available today, and they frequently work with large datasets or search multiple purpose spaces. The demand for more cost-effective, energy-efficient and proficient computing devices and systems will expand throughout science, engineering, business, government and entertainment, driven by society's achievable ideas of understanding extremely sophisticated phenomena in natural and human-constructed structures (Stoller et al. 2019).

2.19 Drones

The advancement of technological developments and the emergence of different requirements in various areas of life have caused drones to start to be mentioned more often. They are one of the most emerging technologies in the last years, actively used in many different areas including military, delivery, agriculture, etc. As a technological term, unmanned aircraft or unmanned aerial systems are called drones, which can be defined as remotely controlled or autonomous flying robots. A more detailed definition from Valavanis and Vachtsevanos is that drones are unmanned aerial vehicles or flying machines that do not have a human pilot or passengers on board (2015). Drones, which were first utilised in the military in the nineteenth century, have since become more widespread in all parts of daily life (Dalamagkidis et al. 2012). Drones are most significantly related to the military, although they are also utilised for rescue operations, surveillance, route planning and weather forecasting (Udeanu et al. 2016). Drones come in a variety of types due to their wide range of applications. The technical characteristics of drones should be discussed to have a better understanding of them. Vergouw et al. state that drones can be categorised according to their kind, fixed-wing or multirotor, autonomy, weight and shape and energy source. These dimensions are significant for the drone's cruise range, maximum flying time and payload capacity, among other factors. As stated previously, drones are an important technical feature of drones. Two of the most common drone types are "fixed-wing drones" and "rotary-wing drones". The vast majority of current drones belong to one of these two categories (2016). These two broad drone categories have their own

The Technical Characteristics of Drones			
Size	**Range**	**Wing**	**Power**
Nano <30 mm	Close-range < 0.5 miles	*Rotary-wing*	Electric
		Single Dual Rotors	
Micro 30-100 mm		Multi-Rotor	
Mini 100-300 mm	Mid-range 0.5–5 miles	Tricopter	Gas
		Quadcopter	
Small 300-500 mm		Hexacopter	
		Octocopter	Nitro
		Fixed-wing	
Medium 500 mm - 2 m	Long-range 5 > miles	Low-wing	
		Mid-wing	Solar
Large >2 m		High-wing	
		Delta-wing	
		Hybrid	

Fig. 2.51 Technical characteristics of drones. (Jiménez López and Mulero-Pázmány 2019)

set of positive and negative attributes. Fixed-wing drones, to give an example, have a higher maximum speed and a greater capacity, but they ought to sustain constant forwards mobility to stay above, making them unsuitable for applications that require stability, such as close inspection. On the other hand, rotary-wing drones can travel freely and stay fixed in the air, despite their mobility and payload limitations (Zeng et al. 2016). Hybrid drones are outside of these two categories. Hybrid drones are expected to become more common in the future as manufacturing and design improvements and expenses descend (Saeed et al. 2018). Figure 2.51 demonstrates the abovementioned characteristics of drones in better detail.

Drones, whose capabilities are improving, and their areas of application are expanding, are becoming more important and popular each day. Drone technology is on the rise because it has the potential to disrupt large industries. According to Giones and Brem, drones are anticipated to become as normal as smartphones are now. They have autonomous functionalities due to advances in artificial intelligence, image processing and robotics, which have increased their revolutionary potential (2017). Another reason drones, whose capabilities have increased in parallel with technology advancements, are significant is that they may be used to tackle global issues. According to Kitonsa and Kruglikov, drones may be a big force for good since they have an immense opportunity for being utilised to achieve the sustainable development goals (SDGs) of the United Nations. Hunger, diseases, poverty and other issues plague developing countries; drone technology is important since it can help solve many of these issues (2018). The role of drones in resolving these issues is discussed in further detail in Fig. 2.52 with application areas.

The new era of drones promises the autonomous system of flying for robots. Drones can be associated generally with applications of defence. They can also greatly impact civilian duties such as agriculture, transportation, protection of the environment, communication and disaster affect minimisation (Floreano and Wood 2015). Drones can make a difference in distorted areas for light package supplies transportation which can be more important after a disaster occurs (United Nations 2021). A new vision with a wide range and perspective, locations that are hard to reach, static images, video records and detection of objects will come in with drone technology developments. Drone-based datasets will be used in different fields, such as visions of computers and related areas of them (Zhu et al. 2018). Also, passive or active

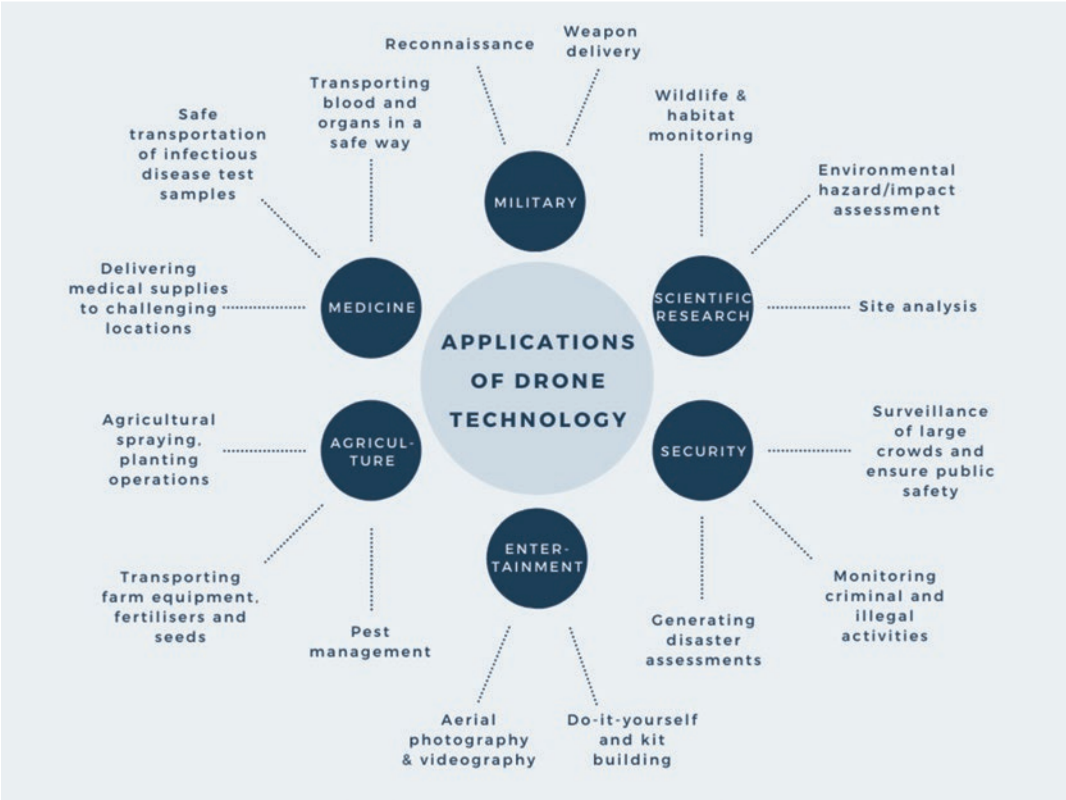


Fig. 2.52 Applications of drone technology

sensors will become more important in drone development, and they will be designed specifically. 3D modelling for landscapes will be easier with drone technology development. Drones will displace the kites, balloons and blimps, helicity, which are used for inexpensive low-level aerial photography. Increasing drone instrumentation, such as GPS, can have effects on cost, payload, range of flight and drone structure, and lower-cost platforms should be improved; drones can be more automated (Campana 2017). Additionally, in our day, drones are used in a large scale of civilian activities, such as photographing intense moments in extreme sports, construction surveillance, racing and agriculture, and their use is expected to expand in the upcoming years. The Federal Aviation Administration (FAA) of the USA estimates that the registered drone numbers in its database will reach 3.8 million by 2022 (Tezza and Andujar 2019).

(a) *Military*

Drones have a vital role in the military sector, which is where they were first utilised. Military forces use unmanned aerial vehicles (UAVs), known as drones, to attack high-value stationary targets. Unmanned ground vehicles (UGVs) can have explosives and supplies for forces on the ground, for example, heavy weapons or more ammunition, but also provide real-time video monitoring capabilities. Ground forces' combat power is increased by minimising their physical load (Fernández Gil-Delgado 2021). According to Pobkrut et al. a "survey drone" is a kind of drone designed for military purposes that use sensors such as an infrared camera and a motion detector to detect threatening targets. This means the drone is expected to possess the ability to visually detect the objectives. It is extremely difficult for a visual survey drone to detect hidden or invisible targets, so installing a system that imitates a nose to a fixed-wing drone to sense and categorise chemical volatiles or odours is a very useful method for locating hidden targets containing threats such as bombs and chemical weapons. The rationale of this method is that usually, the explosive parts of mass destruction weapons leak some gases that can be identified. Such technology will increase the survey drone's productivity and considerably benefit security services (2016).

(b) *Scientific Research*

Drone research was started for the military, and after that, it has developed in different fields of science. As electronic technology has become smaller and cheaper, camera and sensor costs have fallen, and the battery power has increased. Previously, scientists could only examine the globe from above using manned planes or satellites; nowadays, they can expand, enhance and refine their studies thanks to drones. Drones are also used to monitor rivers to predict floods. They can locate places in which trees are illegally cut down. They can detect the growth of algae as well as the trespassing of saltwater into water bodies. Plant species are determined, and diseases in forest trees are detected. In the field of energy, drones are used to detect methane leaks in the production process of oil and gas and to monitor the effect of pipes and solar and wind installations (Cho 2021).

(c) *Security*

Drones are quite popular for delivery services. UAVs which are used to transport packages, food, medical equipment and other commodities are known as "delivery drones". To accomplish a delivery, a drone has to specify the personal information of the customer and any data exchanged between the drone and the customer's site, such as a landing area, needs to be shielded from eavesdropping and drone capture. Available operating systems of drones, on the other hand, lack security support and depend solely on security measures at the link level (e.g. Wi-Fi protected access). As a result, they are subject to common malicious attacks such as impersonation, manipulation, interception and hacking. Drones are also vulnerable to physical capture attacks because they are mobile and may pass through hazardous places. Outside landing locations that are not protected are especially vulnerable to physical capture by attackers. The security-related concerns for delivery services, such as authentication, non-repudiation and secrecy, must be addressed. Security measures to combat physical capture assaults are also necessary for delivery drones or outdoor landing places. A flexible system design is necessary to meet these security concerns for a broad range of parties and applications (Seo et al. 2016).

(d) *Entertainment*

In the entertainment industry, drones are frequently used. According to a survey, drones have a great potential for use in the entertainment industry with the help of AR (augmented reality) and VR (virtual reality) technology and will become more popular in visual arts, interactive tourism and live entertainment (Kim et al. 2018). Drone hobbyists have a wonderful experience building their own drones and competing in drone contests. In addition, drones have made aerial photography, which is usually highly expensive, more affordable.

(e) *Agriculture*

Drones are used extensively in agricultural operations. Drone technology offers significant benefits, such as precise monitoring of regions challenging to access by man, tracing illegal transactions, wildfire observations and crop yield surveillance on agriculture farms. Farmers may use drones to examine farm conditions at the beginning of any crop year. They also create 3D maps for soil testing. Drone-based soil and field studies also offer irrigation and nitrogen management data in fields for improved crop development (Puri et al. 2017). Drones in agriculture and smart farming are more effective than satellite technology since they can provide farmers with an overview of their fields while keeping close to

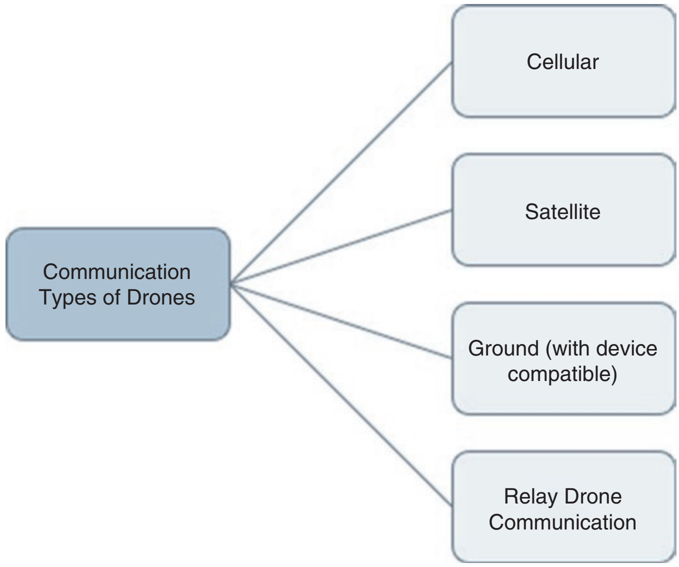


Fig. 2.53 Communication types of drones. (Yaacoub et al. 2020)

the land and therefore delivering more exact evaluations (Tripicchio et al. 2015).

(f) *Medicine*

Medicine is another field where drones are actively used and where their application is becoming increasingly prevalent. Providing catastrophe assessments when access routes are heavily limited; delivering first-aid packages, medicines, vaccines and blood to remote areas; and supplying safe transport of test samples and kits in areas with high contagion risk are commonly used applications of drones in the healthcare industry, and despite certain regulatory restrictions, drones have the potential to revolutionise medicine in the twenty-first century (Balasingam 2017). Drones, which have shown to be effective in the field of medical and health, appear to be promising for future advances in this sector.

(g) *Transportation*

Drone delivery is being considered a potential answer to future last-mile delivery issues. Meantime, the autonomous mobility trend provides flexible transportation within a city, reducing future traffic congestion (Yoo and Chankov 2021).

The four main categories of drone communications are drone-to-drone (D2D), drone-to-ground station (D2GS), drone-to-network (D2N) and drone-to-satellite (D2S). The diagram of communication of drones is shown in Fig. 2.53 (Yaacoub et al. 2020). Figure 2.54, on the other hand, illustrates the future application areas of drones.

The future of drone applications is evolving in parallel with the development of emerging technologies and is also considered as the maturation of their current usage areas. In the military, this is the situation. Conducting short-range surveillance is already mature and used, yet long-range surveillance and image capture are not at the maturity level. They are expected to be in 2–5 years. It is predicted that offering multimedia bandwidth by emitting signal/video/sound will mature in 1–3 years. In addition, it is expected that human transportation and cargo delivery via drones will reach advanced levels (Cohn et al. 2017). Also, the advancement of artificial intelligence for smartphones which are capable of recognising human users, understanding their behaviours and constructing representations of their surroundings, will continue to drive rapid advances in cognitive autonomy. Without the use of wearable devices, face recognition and gesture-based interaction will become largely available

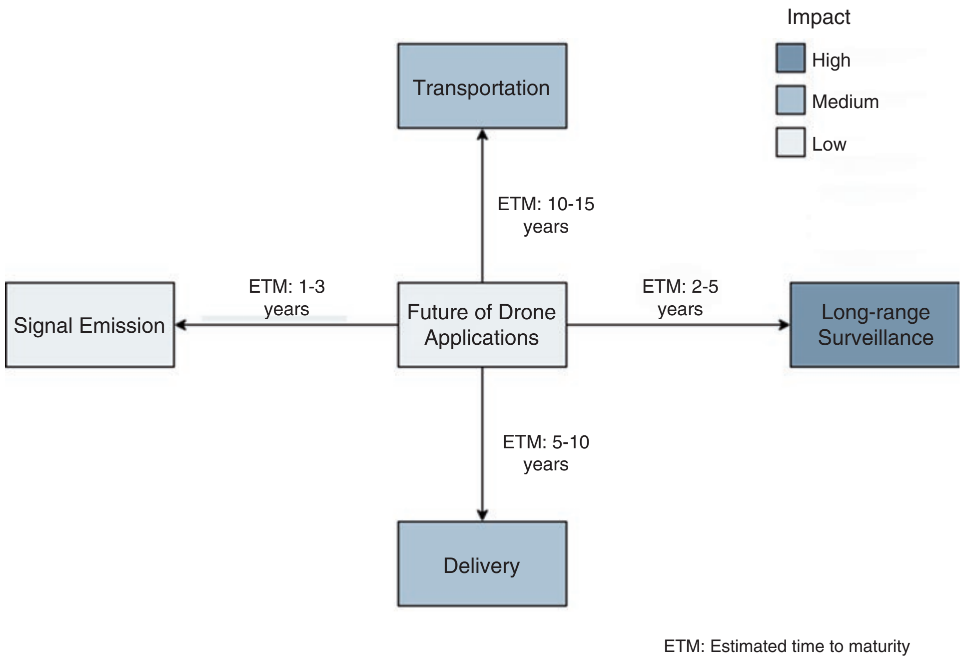


Fig. 2.54 Future of drone applications. (Cohn et al. 2017)

for hobby and toy drones over the next few years, to give an example, by attaching small drones with gaming-industry-developed human motion-detecting sensors (Floreano and Wood 2015).

2.20 Edge Computing

Edge computing is one of the trending and promising technologies that attract the attention of many users and researchers. Computational services and needs are satisfied better when using edge computing. Edge computing services allow the collection of data or perform a specific action in real time. Edge computing can be considered an alternative approach to the cloud environment, as real-time data processing takes place near the data source, which is considered the "edge" of the network. This is because applications that run with edge computing physically run on the site where the data was generated, rather than in the central cloud system or storage centre (Jevtic 2019). Until the development of edge computing, there were four waves in the history of computing, including edge computing: monolithic systems, the technology of the web, cloud computing and edge computing (Mannanuddin et al. 2020). Figure 2.55 illustrates the history of computing with these four main waves.

To begin with, it is needed to understand cloud computing to understand better what edge computing is. In brief, it is the storage where one's database is in. So, the idea of edge computing is to push the cloud services closer to the edge of the network. It gathers the data from the beginning, and the data processes at the very machines that gathered the data from the beginning. Thus, edge computing can be called a decentralised cloud. Also, edge computing is remarkably close to IoT technologies too. At this point, as IoT technologies gather the data, edge computing is the right service for it.

Cloud computing's centralised processing mode is insufficient to manage the data generated by the edge. The centralised processing paradigm transfers all data across the network to the cloud data centre, which then uses its supercomputing capability to solve computing and storage issues, allowing cloud services to generate economic

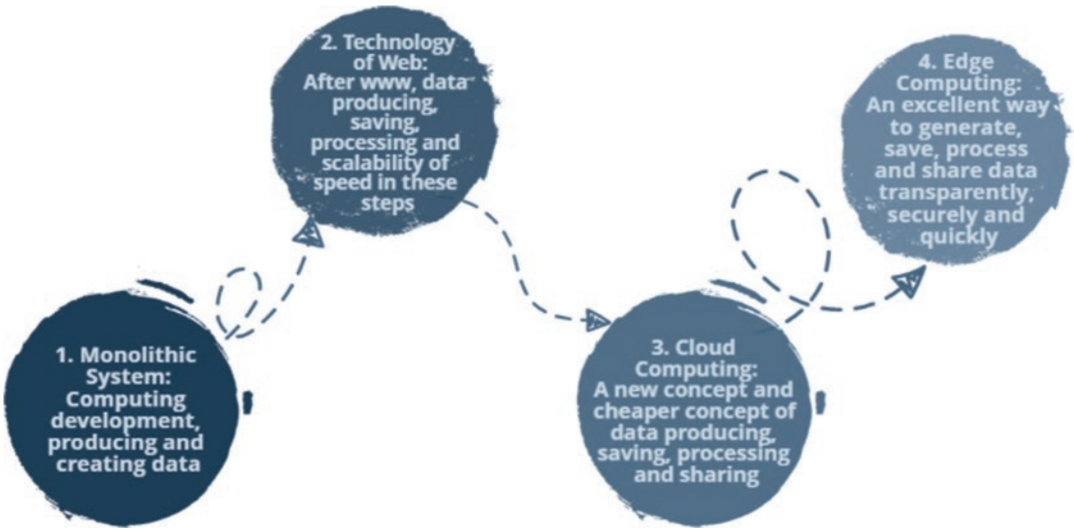


Fig. 2.55 History of computing

benefits. Traditional cloud computing, on the other hand, has significant drawbacks in the context of IoT, such as:

- *Latency:* Latency becomes more obvious in traditional cloud computing due to additional data transmission and reception time to the central cloud and end device, respectively. If the tolerable latency is surpassed, its consequences might be horrendous, as in the case of latency problems in high-speed autonomous vehicles.
- *Bandwidth:* The real-time transmission of massive amounts of data generated by edge devices to the cloud will put a lot of strain on network bandwidth.
- *Availability:* As more Internet services migrate to the cloud, the availability of these services has become a necessity in everyday life.
- *Energy:* Data centres consume a lot of energy.
- *Security and Privacy:* Leaking or examining information about private life in the system is among the possible vulnerabilities. For example, when the camera or photo images are transmitted to the cloud, the recordings/images that are not wanted to be seen will be in the cloud (Shi et al. 2019).

Edge computing is caused by the need for overloading, latency and inability to perform real-time analysis when using cloud computing. In edge computing, the data that comes from cloud servers is transmitted directly to a network edge. This brings users and services together. If the performance features of edge computing are considered, it can be seen that bandwidth is high, latency is extra-low and real-time access in the network is faster. As a result, it reduces the load of the cloud and offers low-latency processes. Cloud technology has a centralised structure, while edge computing has distributed servers and has a decentralised system (Khan et al. 2019).

There are two kinds of edge computing: edge server, which is a piece of IT equipment. The other one is edge devices, and this is a piece of equipment that was built for some purposes. For example, suppose a vehicle automatically calculates fuel consumption. In that case, sensors based on data received directly from the sensors, the computer performing that action is called an edge computing device or simply "edge device" (El-Sayed et al. 2017). Nowadays, all modern electronic devices can compute. Thus, this means that people can work everywhere, even where they did not consider before. To sum up, edge computing allows reaching the devices that we want and doing our job. So, these emerging or modern technologies are pieces of IT equipment, and they have servers. Figure 2.56 summarises the components of edge computing.

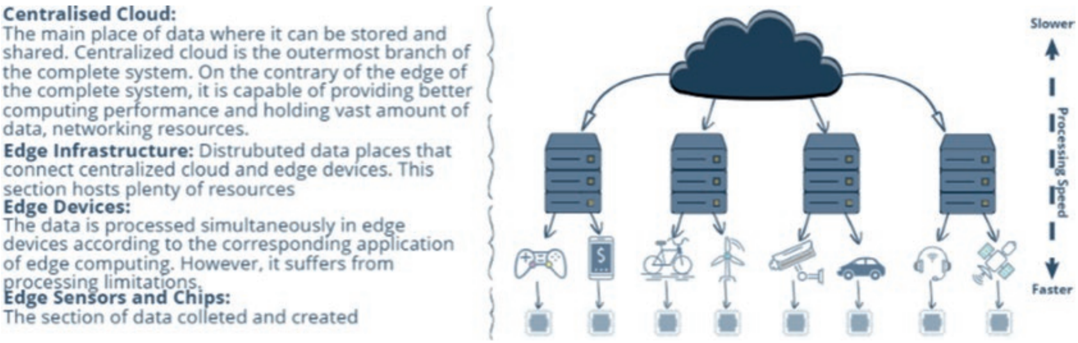


Fig. 2.56 Infographic of edge computing. (CBINSIGHTS 2019)

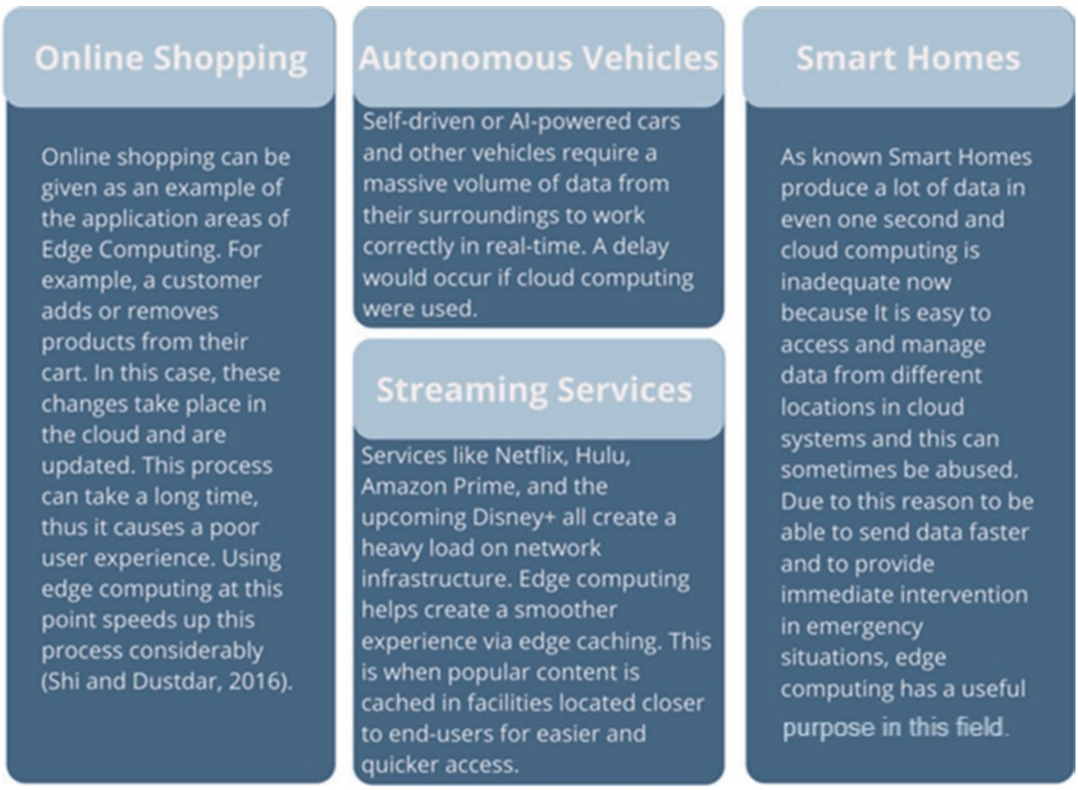


Fig. 2.57 Applications areas of edge computing. (Khan et al. 2019)

When a new technology emerges, it is quite essential to understand where it can be utilised. The best way to demonstrate the use of this method is through some key edge computing examples. Figure 2.57 compiles some application areas and examples of edge computing used for various scenarios to comprehend and internalise it better.

Edge computing aims to bring computing resources from a hyper-scale cloud data centre, which may be located a bit farther away (at the network's "core"), closer to the user or device at the network's "edge". This method lowers network latency and gathers computing power to process data close to its base. Mobile applications could leverage artificial intelligence and machine learning techniques more effectively over the edge network since they are currently fully reliant on the computing capacity of mobile processors (Стельмах 2020). Edge computing is everywhere as we need vehicles, houses, planes, buildings, etc. Low latency, high bandwidth, device processing, data offload and trustworthy computing and storage are the major advantages of edge technologies (Ekudden 2021). Edge computing offers some advantages to its users. The following are the advantages of edge computing listed by Mannanuddin et al. (2020):

- *Increasing the work performance:* One of the biggest advantages of this technology is that it has a fast response time and minimum delay because it is closer to the end-user than cloud technology.
- *No limit for the dimension of expansion:* Again, due to its proximity to the end-user and real-time analysis, it does not need any memory limit and is always open to expansion.
- *Protect your data at a high level:* This advantage can be exemplified as follows, considering a single cabinet with all valuables, these items will be under threat in a possible attack. However, if these items are allocated to small but numerous closets, the loss that will occur if a locker is unlocked is very small compared to all existing items.
- *Reducing infrastructure costs:* The data is different, and the demand for data is not exact. Some of the important or expandable data that comes from cloud systems are used by edge nodes. In this way, the cost of the process is decreased by edge computing.
- *Efficiency and reliability in business:* Since edge computing only stores the required amount of information on its nodes, there will be no loss of data and no delay in case of an interruption.

The data that has been taken from cloud services are transmitted easily and fast; the transmitted data and the velocity increase. In IoT, pulling data from sensors and going to process will be yielding and safe because wireless communication modules spend a lot of energy. However, edge computing does not. Normally, data is produced and presented to the consumer, but nowadays, data must also be obtained from consumers thanks to social media. Therefore, the cloud network cannot be located in one place. Processing and storing data at the edge provides better protection than transferring that data to a cloud (Shi et al. 2016).

Edge computing, day by day, is affecting more and more areas. According to Techjury, the total data volume will be around 40 trillion gigabytes by the end of 2021, with a generation rate of 1.7 megabytes per person each second (Tadviser 2019). First and foremost, edge computing is in high demand in situations where judgments must be made quickly. Autonomous transportation systems must be able to react to changing traffic conditions quickly, changing speed, direction and even the entire route. It is believed that they will be connected to the central cloud in some way, but operational decisions will have to be made "on board". IoT systems are developing and attracting more data. A reliable source will be needed to process, store and optimise the accessed data. However, edge computing is not developed enough to do these yet. An efficient scheduling algorithm that manages and controls this edge computing is also developed for energy efficiency (El-Sayed et al. 2017). One more example is the "intelligent" IoT sphere. When it is compared to the last generation of IoT, the new generation with edge computing will be more reliable. The efficiency and reliability of such a system are improved by processing data at the border (in local data centres, micro-clouds and even on the devices themselves) (Орлов 2019). As mentioned in the smart home part, sometimes cloud computing is not safe, and data is accessible from everywhere, and space problems can happen, so, in the future, this technology will develop about cloud offloading. In this direction, navigation systems and real-time applications games, augmented reality will develop. After the latest developments in social media, with mobile phones' smartness, many video analytics technologies are insufficient. Therefore, it will be used in the future, especially to increase security, for example, to catch a criminal, be quick and intervene immediately (El-Sayed et al. 2017).

2.21 Energy Storage

Energy systems are critical for gathering energy from different sources and transforming it into the energy forms necessary for use in various industries, including utility, manufacturing, construction and transportation. Energy sources can be used to meet consumer demand since they are easily storable while not in use. Early societies used rocks and water to store thermal energy for later use. Flywheels have been employed in pottery manufacturing for thousands of years. With the industrial revolution, new energy storage systems began to be used by people in many areas. Thermal, mechanical, chemical, electrical and magnetic energy may now be stored, converted and used thanks to many different methods. Modern energy storage devices have a wide range of uses in everyday life, for example, battery-operated portable devices such as computers, power banks, tablets, phones and smartwatches. Grid energy storage systems are necessary to maximise the introduction of energy efficiency. The electrochemical energy storage system, known as a battery system, has huge potential for grid energy storage. Energy storage methods can be used in a variety of applications. The form of transformed energy mostly determines the categorisation of energy storage systems. As can be seen from Fig. 2.58, energy storage systems are grouped under five main headings: mechanical, thermal, chemical, electrochemical and electrical energy storage. The following topics include energy storage systems and technologies, their use areas and potential future.

(A) *Mechanical Energy Storage*

Five different storage systems for mechanical energy storage systems are examined in this section.

(a) *Pumped Thermal Energy Storage (PTES)*

The heat pump system is utilised to transform the electrical energy and store it as thermal energy in this system. This technology is currently an emerging technology. This system consists of four different system elements. The system consists of two solid-filled storage tanks plus a thermal engine that can perform both the functions of a heat pump and a heat engine. While electricity is utilised, the machine in the system works as a heat pump and gas is produced at high pressure and temperature. While the hot gas produced here is transferred to the hot storage tank, cold gas is injected into the cold storage tank. In this way, the gases are pumped into hot and cold stores and diffused into the solids that fill the tanks. In the discharge cycle, the machine used in the system works as a heat engine. It uses two storage temperature differences to operate the electric generator here. While the gas in the high-temperature storage tank has high-pressure values, the pressure value in the tank is kept at ambient pressure in low-temperature storage. The pressure difference between these two storage tanks is determined by the temperature difference, the solid material used and the working fluid (Barbour 2013). While these systems have a storage capacity from kilowatt to a megawatt, they can perform this storage process at 70–80% efficiency values (Ruer et al. 2010).

(b) *Compressed Air Energy Storage (CAES)*

Compressed air energy storage is an old technique to store energy as the first CAES plant was built in 1978. Large CAES facilities utilise underground places such as salt mines and rock caverns as storage locations (Gallo et al. 2016). In CAES, electricity using compressors catches and compresses the air. Then, the electrical energy used by compressors converts into the potential energy of compressed air. When energy is demanded, stored air is released and goes through gas turbines, where turbines convert the energy into electrical energy. The air compression process generates heat. Different sub-methods of CAES, such as D-CAES (diabatic), A-CAES (adiabatic) and I-CAES (isothermal), are named based on their approach to waste heat (Budt et al. 2016).

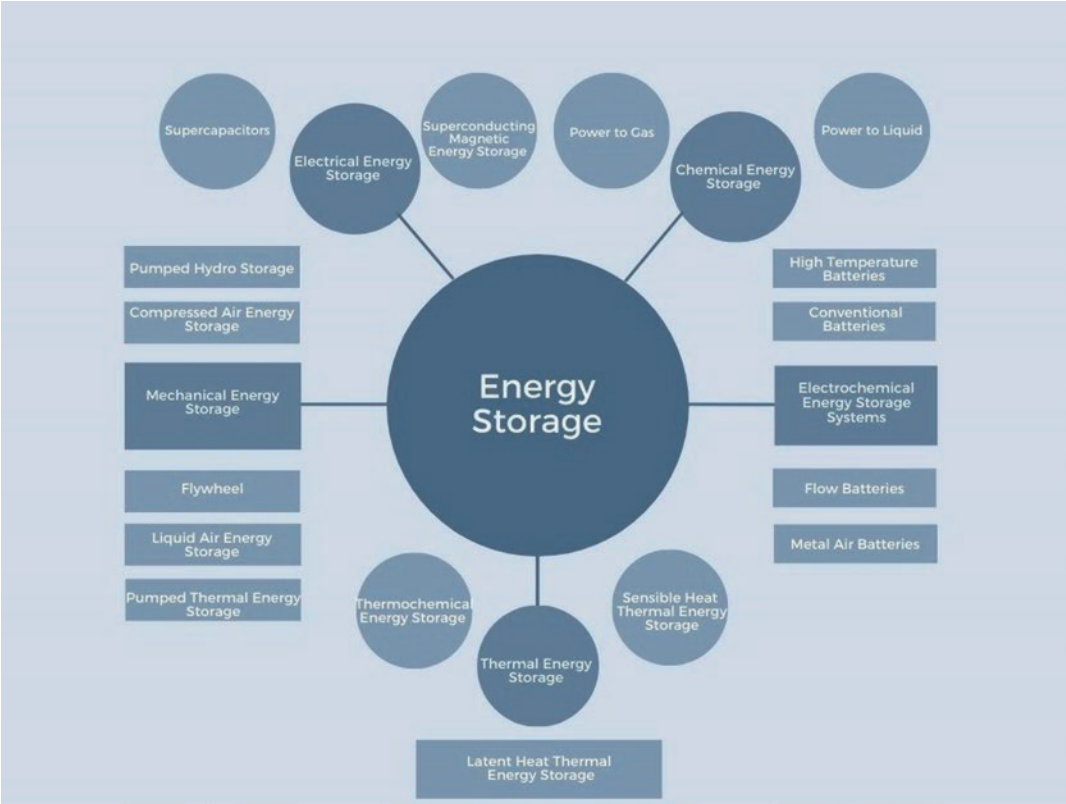


Fig. 2.58 Energy storage technologies

(c) *Flywheel*

The stored energy is in the rotational kinetic energy form in flywheel systems. The motor is used to charge this system. This motor utilises electricity for the rotation of the flywheel rotor. While the discharge process is carried out in the system, the same engine performs as a generator and produces electricity by reducing the engine speed. In these systems, the power ratio is determined by the characteristics of the power electronics and the engine-generator set in the system. The storage capacity also depends on the rotor speed, material and shape (Chen et al. 2009). There are two different flywheel configurations. These configurations depend on the maximum rotor speed. High-velocity flywheels could get 100,000 rpm, and composite materials are preferred in these systems. In low-speed flywheel systems, they operate at less than 10,000 rpm. Steel is commonly preferred as the rotor material in these systems. Due to the engines and materials preferred in high-speed flywheel systems, system costs are higher than low-speed flywheel systems (Lund et al. 2015). When they are modularised, the storage value can reach MW levels. These systems are capable of operating with 75–85% efficiency rates, and they are important storage alternative systems as they are fast-acting and long-lasting systems (Hadjipaschalis et al. 2009).

(d) *Liquid Air Energy Storage (LAES)*

Liquid air energy storage is an emerging technology that enables the storage of energy by storing liquified air in tanks. Unlike PHS and CAES, LAES does not require broad land to build a storage facility, and there is no significant environmental issue caused by LAES (Gallo et al. 2016). Therefore, LAES can be considered geographically independent and environmentally safe. LAES takes thermal and electrical energy as inputs and outputs thermal and electrical energy. Air liquefaction and power generation are two different cycles that act as the opposite of the other. Gaseous air is captured by a compressor and liquified by a condenser at the liquefaction cycle. This liquid air can be stored in a tank. When energy is demanded, the power generation cycle becomes active, and liquid air is released from the tank and pumped into a heater. Heated air moves through a turbine and spins it (O'Callaghan and Donnellan 2021).

(e) *Pumped Hydro Storage (PHS)*

The PHS technique stores energy as water's potential energy by creating two water reservoirs where one is placed lower. Water is pumped from the lower reservoir to the upper one when stored energy is needed. Once power is required, blockings between the reservoirs are removed, and turbines produce energy while water travels to the lower reservoir (Rehman et al. 2015).

(B) *Electrochemical Energy Storage Systems*

(a) *Conventional Batteries*

- *Lead-Acid*

This technology has been used for 150 years, especially in the automotive industry. The components of this technology are lead metal as well as oxide electrodes, also a solution of sulphuric acid (Chen et al. 2009). Whereas lead and lead oxide transform to lead sulphate, as the concentration of the electrolyte decreases in the discharge cycle, the deposition of the lead and increasing concentration of the electrolyte that take place on the anode occurs in the charge reaction. High efficiency and low cost are advantages of lead-acid batteries; nevertheless, low cycle life, low specific energy and the toxicity of the lead are disadvantages of this type of battery (Beaudin et al. 2010).

- *Lithium-Ion*

Lithium-ion (Li-ion) batteries are a high energy density, rechargeable energy storage technique that employs lithium ions as the main component. Lithium atoms in the anode are ionised during a discharge cycle and recombined with their electrons in the charge cycle. The electrolyte provides a transfer medium between the anode and the cathode, but this electrolyte is highly flammable. High energy density, extremely low self-discharge rate and relatively low price make Li-ion batteries popular in various areas.

- *Nickel-Cadmium*

Nickel hydroxide is the cathode, and cadmium hydroxide is the anode in this battery. The anode reaction is the conversion of the cadmium hydroxide to cadmium metal, whereas the cathode reaction is the transformation of nickel hydroxide to nickel oxyhydroxide (Gallo et al. 2016). The properties of this type of battery are long cycle life (1000–1500 cycles), elevated specific energy (55–75 W h/kg) and so on. However, the toxic property of cadmium is the negative side of this technology. Also, nickel-metal hydride batteries can be obtained by removing the cadmium in the system. This battery is an environmental version of nickel-cadmium batteries. When the energy density increases, the self-discharge and reduced durability occur in the nickel-metal hydride batteries (Gallo et al. 2016).

(b) *High-Temperature Batteries*

- *Sodium-Sulphur Batteries (NaS)*

Sodium sulphur (NaS) batteries started to commercialise in 1984. This battery technology contains molten sulphur and sodium ions at cathode and anode, respectively. A high temperature is required for this technology to keep sodium and sulphur in the liquid phase. Due to this situation, this technology can be designated as high-temperature batteries. Besides, the electrodes are made from alumina, which only gives sodium transportation in the electrolyte. To keep this battery at a high temperature, electrical heaters are used in this type of battery. Electrical heaters give rise to discharge capacity losses (Schlumberger Energy Institute (SBC 2013).

- *Sodium-Nickel Chloride (Na-NiCl$_2$)*

Sodium-nickel chloride batteries have molten materials at their electrodes. The first investigation started in the 1970s, and General Electric has been searching for this battery since 2007. An Italian company FIAMM produces commercial sodium-nickel chloride battery systems (Gallo et al. 2016). $NiCl_2$, or the mixture of $NiCl_2$ and $FeCl_2$, behaves as active material in the cathode. Also, sodium-nickel chloride batteries include beta-alumina electrolyte and molten sodium chloroaluminate ($NaAlCl_4$). This type of battery system has high specific energy, efficiency and cycle life; however, the disadvantage of this system is that the heating up from the frozen state of the battery takes a long time, nearly 15 hours (Gallo et al. 2016). Na-NiCl is safer than Na-S batteries. Because when a failure occurs in the electrolyte, molten sodium initially gives the reaction of solid chloroaluminate. As a result of this reaction, non-dangerous products also inhibit any further reactions (Gallo et al. 2016).

(c) *Flow Batteries*

To generate electricity, flow batteries use chemical reduction-oxidation processes. The anolyte and the catholyte, two chemical solutions, are held in tanks separated by a membrane. The differential charge levels on either side of the membrane that is used as potential are referred to as redox (Ferrari 2020). Ion exchange occurs when liquids are pumped over the membrane, causing an electric current to be generated, with the charge being supplied or withdrawn via two electrodes. The energy capacity is solely determined by tank size, while the power is determined by anode surface area. The most popular electrolytes are vanadium and iron solutions (Ferrari 2020).

(d) *Metal-Air Batteries*

This type of technology can be designated as emerging technology due to promising concepts for the future. This technology utilises the oxygen from the atmosphere in the porous cathode and metal electrodes as an anode – for instance, sodium air, lithium-air, zinc-air and magnesium air. High specific energy can be obtained with this technology. Although this technology has not reached its potential, sodium air batteries have great interest due to the abundance of sodium in the world and easiness of reaction (Hartmann et al. 2013). Two properties need to be developed: cost and life cycle. The EU determined the 3000 life cycles as an objective (Gallo et al. 2016).

(C) *Electrical Energy Storage Technologies*

(a) *Supercapacitors*

Capacitors store electric charges; however, they are different from batteries. Capacitors can be charged much faster than batteries and stabilise the circuit's electric supply. Supercapacitors are types of capacitors that have higher capacitance values than the other capacitors. But they have lower voltage limits. They are also called ultracapacitors in some resources. Electrochemical capacitors known as supercapacitors are used for fast power delivery and recharging (Simon et al. 2014).

(b) *Superconducting Magnetic Energy Storage (SMES)*

Energy storage via decreasing temperature below a critical temperature principle is utilised for this type of storage system. This technology can directly store electricity. These storage systems induce a dynamic electric field or generate a magnetic field by passing a current through a superconducting coil. Since the coil is made of a superconducting material, the current can flow through it almost without a loss (Luo et al. 2015).

(D) *Chemical Energy Storage Technologies*

(a) *Power-to-Gas (PtG)*

Power-to-gas technology depends on the conversion of energy. The working principle of this technology is that electricity is taken into the system and transferred to the electrolysis machine. The electrolysis process is carried out here, and two outputs, hydrogen and oxygen, are obtained. These products are then converted to methane by a process called mentation. After this process, the product that comes out is a kind of synthetic natural gas or substitute natural gas. This created product has the same properties as natural gas and can be transferred, used and stored just like natural gas. This system functions as an efficient energy storage system. In this system, if renewable energy sources are used as an energy source, and carbon capture technology is used in the mentation process, the resulting gas turns into a carbon-neutral gas (MAN 2021).

(b) *Power-to-Liquids (PtL)*

As the name suggests, power-to-liquid technology is a technology that converts energy into various liquids. The main sources used in this technology are electricity which is produced by renewable energy sources, water and carbon dioxide. Here, electrolysis is carried out with the help of electricity and water, and hydrogen is produced. The hydrogen obtained as a result of this production and the ready-made carbon dioxide are used for the production of liquid hydrocarbons. It is refined according to the type of hydrocarbon produced. There are two main production routes to realise liquid production in this technology, the Fischer-Tropsch (FT) pathway and the methanol (MeOH) pathway. With these production methods, the desired liquid hydrocarbons are produced (Schmidt et al. 2016).

(E) *Thermal Energy Storage (TES) Technologies*

One type of energy storage system is thermal storage of energy. In these systems, thermal energy is stored by heating or cooling the material or environment. The energy to be stored can come from waste cold, waste heat or thermal solar energy. In addition, electrical energy can be converted into a storage source for these systems after it is converted into heat energy (Gallo et al. 2016). The energy here can be stored daily, weekly or even seasonally, then stored energy could be utilised to heat, cool or generate power. Thermal energy storage systems are divided into three in themselves. This distinction is as follows.

- Sensible heat thermal energy storage (SH-TES)
- Latent heat thermal energy storage (LH-TES)
- Thermochemical energy storage (TCES)

The sensible heat thermal energy storage method is the most commonly utilised method for thermal energy storage systems. The liquid or solid used in such systems is heated, increasing its temperature. Then, the energy stored here is released when needed by lowering the temperature of the material. The heat capacity of the material used here is essential. In these systems, materials with high heat capacity are used, so the amount of material used is kept as low as possible. Material thermal properties, material storage capacity and operational temperature values are factors that affect material selection (Hauer 2012). Although these systems are less efficient (50–90%) than other thermal storage systems, they are preferred because of their simple structure and low cost (Connor 2019).

Latent heat thermal energy storage systems utilise the change of phase to store thermal energy. In these systems, phase-changing materials (PCM) are preferred as storage materials. These systems eliminate the two disadvantages of SH-TES systems. The first of these is about specific energy. The obtained specific energy increases between five and fourteen by using this system than the usage of SH-TES. Secondly, while the discharge temperature remains constant in LH-TES systems, the discharge temperature changes in SH-TES systems. The efficiency of these systems is around 75–90%. The PCM used in these storage systems is incorporated into building walls. The temperature of this material decreases due to the decrease in air temperature at night, and it solidifies. With the increase in temperatures during the day, the temperature of the material also increases and the material melts and becomes liquid. During the phase change that takes place here, the wall temperature remains constant and reduces the heat input to the interior. In this way, it can reduce or eliminate the need for air conditioning to cool the environment. This cooling process using these systems is called passive cooling (Abele et al. 2011).

Thermochemical energy storage systems are energy storage systems that perform chemical reactions using thermal energy and convert thermal energy into chemical energy. The purpose of these systems is not to synthesise new products to be used later. In these systems, reversible processes such as hydration-dehydration, adsorption-desorption and redox are used to store thermal energy to be utilised. These systems have a denser storage capacity than other thermal storage systems, and thus the material used for storage is much less. The efficiency of thermochemical storage systems is 75–100%, and these systems are a good alternative for long-term storage. These systems lose almost no energy during the storage period, which makes these systems suitable for long-term storage needs. Storage in these systems is usually carried out at ambient temperature (Abedin 2011).

The energy storage enables the reduction of energy costs, increases energy system reliability and flexibility and integrates different energy systems into the system. In addition, storage systems also contain an environmentalist approach. Energy storage contributes to reducing energy costs both on the producer side and on the consumer side. While the operational costs of energy production companies in frequency regulation or providing spinning reserve services will decrease, the consumption costs of consumers will decrease thanks to the use from the warehouse, which they will make at peak times of energy consumption, especially thanks to storage. In addition, both producers and consumers will not be adversely affected by power cuts that may occur, and it will be possible to mitigate the economic losses due to interruptions to some degree (Energy Storage Association 2021).

The grid's flexibility and reliability increase by the development and integration of energy storage systems. The reliability of the grid is a very important issue for both producers and consumers. Thanks to the storage, in any negative situation that may occur in the grid, consumers are not adversely affected by power cuts because the energy in the warehouse is activated and can be given to the grid. In this way, the costs caused by the negativities will be prevented (Energy Storage Association 2021). In addition, energy storage facilitates the connection of renewable energy sources to the grid. Today, the biggest disadvantage of renewable energy sources is the instability of energy production, and this is one of the biggest obstacles to the choice of renewable energy sources. However, thanks to energy storage, the stored energy is transferred to the grid at the point where renewable energy sources are insufficient to meet the grid needs. In addition, energy storage is important for existing energy production systems. Especially in cases where it becomes difficult to meet the required production due to the sudden increase in demand in the network, these storage systems come into play and ensure that the demand is met. Thanks to the storage, flexibility is provided to the system (Energy Storage Association 2021). The extensive use of energy storage plays an important role in carbon emissions reduction through the common usage of renewable energy sources. In addition, since the networks can operate much more efficiently thanks to storage, the consumed energy will be used more efficiently. Accordingly, there will be a decrease in the amount of carbon released per unit of energy. Since storage systems contribute to decreasing carbon emissions, they also contribute positively to the environment (Energy Storage Association 2021).

There has been a sharp growth in the use of renewable energy sources in recent years, and this trend is projected to continue. Suppose nations maintain their current and previously declared policies. In that case, the worldwide capacity of solar photovoltaic (PV) is expected to reach 3142 GW by 2040, surpassing coal and gas to become the world's greatest energy source. Similarly, wind's proportion in electricity generation will rise from 5% in 2018 to 13% in 2040, with a capacity of around 1856 GW. As a result, the total wind and solar capacity will be 4998 GW. In addition, when hydro and other renewable sources are considered, the overall percentage of energy generation will rise from 26% in 2018 to 41% in 2040 (Hossain et al. 2020). It has become a necessity to meet the energy needs from renewable energy sources since the negative changes in the climate. However, renewable energy production systems cause various problems in continuous energy production, and fluctuations may occur in the production. Storing the produced energy becomes important at this point. In this period of transformation in energy systems, one of the keys to facilitating the transition to renewable energy is the development of new storage systems and the increase in their number. The storage capacity available worldwide in 2014 was around 140 GW (Xylia et al. 2021). By 2020, this amount has increased to 170 GW, and this corresponds to approximately 3–4% of the energy produced today (Kamiya et al. 2021; Xylia et al. 2021). It is aimed to increase the storage level to 450 GW by 2050 (Xylia et al. 2021).

The use of electric vehicles is increasing day by day. This increase brings with it new opportunities. It is possible to use electric vehicle batteries in two different ways for energy storage. One of these is to utilise batteries that have completed their life for energy storage (Renault Group 2021). Batteries in electric vehicles need to be replaced when the capacity percentage drops to 60–70%, but they are still usable (Cagatay 2021). In this case, the batteries taken from the vehicles can be combined and converted into fixed energy storage systems. Another possible usage method is the vehicle-to-grid (V2G) technology. In this technology, vehicles store the electricity they receive from the grid and transfer the stored energy back to the grid when there is a lack of energy in the grid. In this way, mobile energy storage can be provided (Renault Group 2021).

2.22 Flexible Electronics and Wearables

Flexible electronics and wearables (FEAWs) are technologies that support each other and need to be looked at together. The development of one improves the other so that they will be covered together in this chapter. Conventional electronic systems have an inherently rigid and unalterable form. Re-developing these systems by adding features such as flexibility and stretchability allows electronics to be added to a broader range of applications and products where flexibility is required. New form factors and new products can be developed using technologies such as printed electronics. According to experts, the market share of flexible electronics will increase soon. For example, by 2024, the worldwide flexible electronics market is estimated to reach USD 87.21 billion (Grand View Research 2016).

Flexible electronics present many innovative technological developments in the electronics field, such as the flex circuit board. A flex circuit board is a type of printed circuit board with at least one readable feature of the board. Flexible circuits are called FFC (flexible flat cable) and are used by replacing cable wires and connectors. In this case, the flex circuit is designed without electronic components. Another common use includes parts mounted on flexible circuitry such as LED strip and LCD panel interface. The electronic circuit is designed on a flexible plastic substrate, usually polyimide film, which is resistant to high heat to make it suitable for soldering assembly components. Flexible electronics offer low-cost solutions to a wide range of applications such as foldable displays and TVs, e-paper, smart sensors and transparent RFIDs. The main advantages of flexible electronics over existing silicon technologies are low-cost manufacturing methods and inexpensive, flexible substrates. The fact that flexible electronics are light, bendable and portable and require low-cost electronics is also becoming a very interesting material for next-generation consumer products (Cheng and Huang 2009).

Wearable technology is a phrase for items that have acceptable electronic functions and aesthetic qualities, consisting of a simple interface to provide specific activities to meet the demands of individuals. Since wearable technology provides many conveniences to individuals in terms of usage, portability and data utilisation, a considerable amount of attention has been paid to it in recent years, and the market share of wearable technology has increased like flexible electronics. In 2019, the worldwide wearable technology market was estimated at USD 32.63 billion, and it is expected to increase at a compound annual growth rate (CAGR) of 15.9% from 2020 to 2027 (IEA 2021). Flexible electronics and wearables have a mutualistic relationship with each other, as mentioned earlier. These emerging technologies show themselves in many different areas, various sectors such as fitness, finance, entertainment, education, medical and textiles (Wright and Keith 2014). Figure 2.59 demonstrates various sectors where FEAW applications can be seen.

1. Fitness: One of the areas where FEAW is used is health monitoring in sports, for example, pedometer, heart rate monitor that tracks calories burned, distance taken, activity duration, etc., during sports. Moreover, recording these data can provide reference data for both athletic training and health management. In addition to the sports analytic tasks, wearable equipment may be utilised for both physical and mental health controls (Borowski-Beszta and Polasik 2020).
2. Finance: Another area where FEAW is gaining popularity is the financial sector, with its ease of payment. Wearable equipment can conduct financial transactions and save cus-

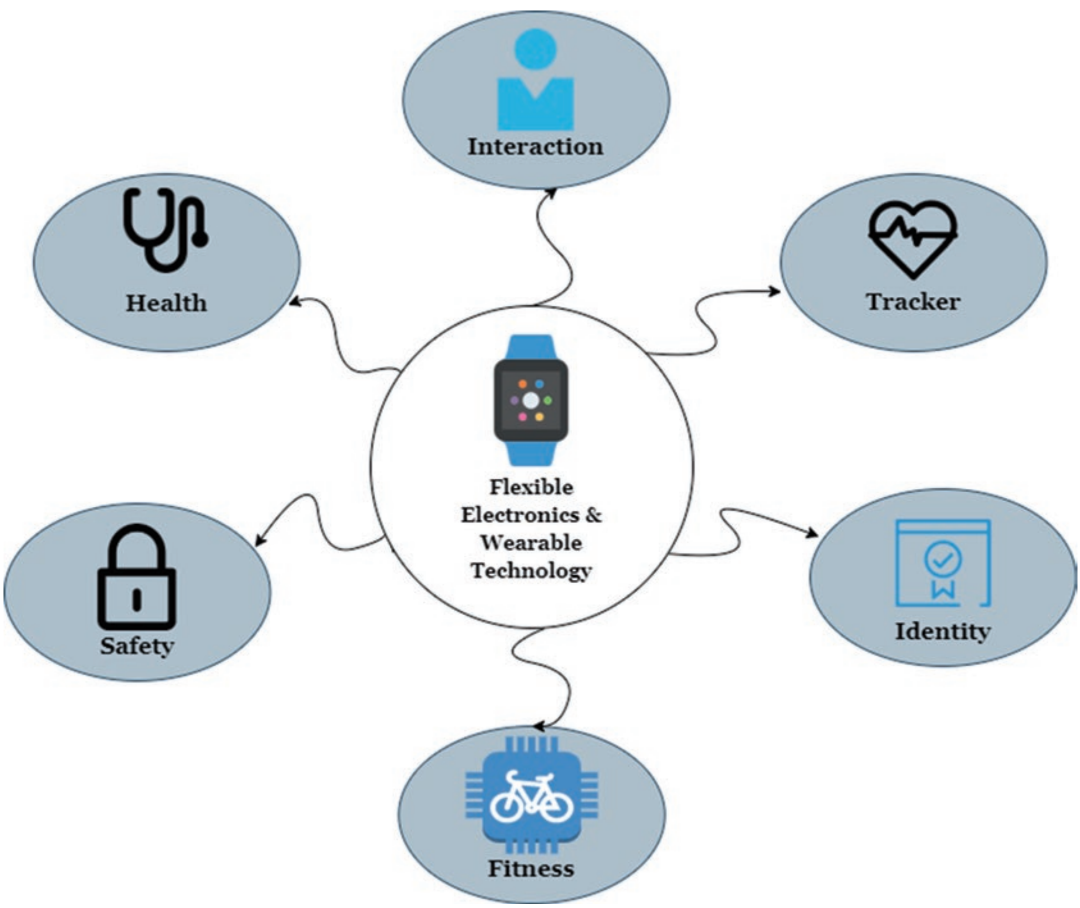


Fig. 2.59 Flexible electronics and wearable technology sectors

tomers' time at payment points by integrating NFC, a wireless communication technology enabling data transfer at an approximate distance of 10 cm (Leong et al. 2013). They may also count as a bitcoin wallet, and it is claimed to be one of the most secure wallets out there with this feature.

3. Entertainment: There are many FEAW integrated into the entertainment industry. CGI technology (computer-generated imagery) added to the costumes allows all effects prepared on the computer to be transferred to movies. In this way, the imaginary world of people can be transferred to real life. Wearable technologies that integrate virtual reality to all of the digital and physical elements to increase the gaming sensation in the real world are also used in the game industry. They are also included in the music industry, allowing individuals to listen to music freely, such as wireless headphones.
4. Education: FEAW could be regarded as "the most important tool utilised in education" in a way that enables remote students to watch and listen to the lectures without physical presence but with a sense of being present in class. It enables students to study differently and without the danger associated. It may present students with actual scenarios and bring them the locations that are difficult or occasionally inaccessible, such as space studies, archaeological courses, medical education, chemical engineering and aviation training (Attallah and Ilagure 2018).
5. Medical: Wearable bioelectronics provides clinicians with real-time monitoring of a patient's physiological parameters, which has interested many researchers and technology companies. Wearable bioelectronics contains three types of sensors: pressure, temperature and biochemical. Tech companies use those sensors to monitor, measure and inject hormones and enzymes into the skin (Parlak et al. 2020). A tech company, Omnipod 5, designed an insulin pump that sticks into the skin and controls blood sugar levels of type 1 diabetes patients (Henderson 2021). Also, many companies try to improve the conditions of individuals with wearable technologies. Sony designed a wearable air conditioner that can fit into a pocket and declares that the air conditioner can decrease body temperature by 13 °C (Byford 2020).
6. Textiles: The textile industry tries to adapt to many developments in flexible electronics. The companies insert the electronics that are sensors, communication modules into textiles. In recent designs, all the components of textiles are electronics which are smart textiles. With the integration of electronics in textiles, clothes transform into electronic devices. That integration inspires tech companies to produce various products (Paret and Crégo 2018).

Flexible electronics are becoming increasingly popular as a result of the numerous advantages they offer. Flex circuits will continue to be employed for a range of applications as more organisations discover their potential for increased customizability, affordability and portability. Flexible electronics are used by a wide range of sectors and professionals in their equipment and products because they provide a variety of benefits such as, but not limited to, being affordable, flexible, customisable, innovative and portable. From a different standpoint, flexible displays and flexible sensors will revolutionise wearable technology by allowing devices to conform to our bodies and clothing while providing increased utility. For instance, the utilisation of FEAW technology has become more medically oriented, an increasing number of wearable devices are being programmed to interact with humans' bodies and collect data that can be used to inform sports science and health research. It will be critical to ensure that these devices are shatterproof, unobtrusive and "unawareable" to design successful healthcare applications. Figure 2.60 summarises certain benefits and drawbacks of FEAW.

Flexible and wearable technologies will become more popular and cheaper to create as a result of advancements in the industry. In addition to having a larger market cap, it will be evaluated to be utilised in other industries in the future (Skilskyj 2018, 2019).

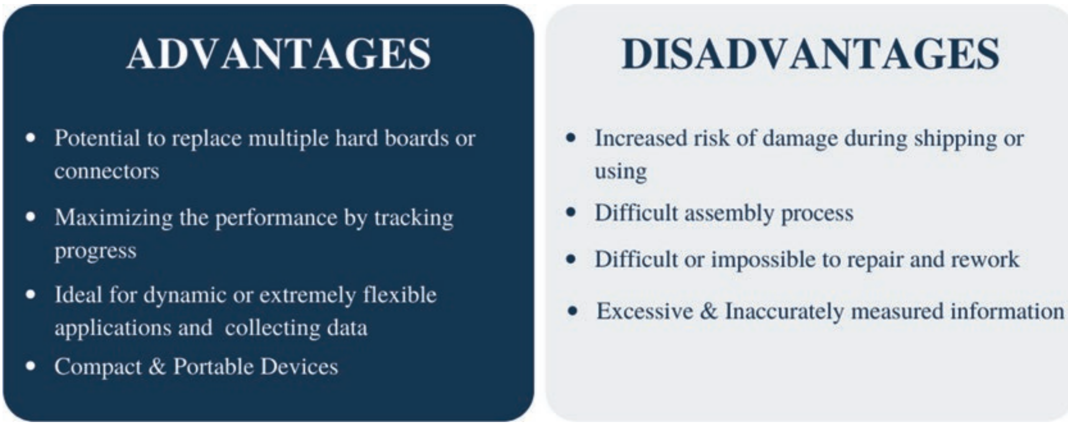


Fig. 2.60 Advantages and disadvantages of flexible and wearable technology. (Lee et al. 2016)

Flexible electronics and wearable technologies have high potential. Soon, they will be able to do things that people cannot even think of right now. Major developments in medical, energy and electronics are coming. Studies in the medical field enabled innovative solutions. One of the featured solutions is electronic skins. Patients will be able to wear a plastic sheet with organic circuits embedded in it if they choose to use electronic skin. The skin can monitor the pulse, oxygen levels and temperature of the user's blood. Users can become more aware of potential health issues and provide invaluable data to their healthcare providers by utilising electronic skin. The UV radiation monitoring patch will also be available in the future (Moser et al. 2016). Users will be able to track how much dangerous UV light they receive using a UV radiation tracking patch. The patch may provide the data directly to smartphones so that people may notice whether they have to search for melanoma and other potentially harmful consequences of UV radiation more vigilantly. Flexible circuits in contact lenses, another development that we will encounter in the field of health, is another technology that we will encounter in the future. Contact lenses with electrically conducting polymers are an intriguing opportunity for the future of flexible electronics. A user may transfer a picture from a TV or computer screen right into their contact lenses with these contact lenses (Watkins et al. 2021). Additionally, sensors integrated inside the lens could potentially detect a user's glucose level and then project that level onto the lens, allowing the user to see it.

Studies in the field of energy continue day by day. One of the most exciting innovations in the energy industry is printable solar panels. Organic photovoltaics (OPVs) are a type of flexible electronics that are expanding solar energy possibilities. An OPV may print solar energy technology into the fabric of your drapes or laminate it onto your window panes rather than requiring solar panels to be placed on a roof. Consumers may see the technology integrated into solar-powered clothes, which could be used to recharge cell phone and laptop batteries (Global Electronic Services 2021). OPV cells are thin and flexible because they are placed on a flexible substrate. Sunlight is absorbed through technology, which then transmits that energy to devices. These OPVs are not only offered to make houses simpler and meet specific demands but may also be considerably cheaper than standard solar panels. The lower cost is primarily since OPVs employ a polymer-based semiconductor layer, whereas most solar panels on the market use more expensive semiconducting materials like silicon. Researchers and business professionals are developing techniques to increase the availability of OPVs and incorporate them into a wide range of products. In the future, experts expect to see a lot more of these OPVs (Watkins et al. 2021).

The last area to investigate in FEAW is electronics. The gadgets and devices that employ flexible electronics will be increased for consumers in the future. For example, foldable smartphones can be given as an example. While some of these modern phones are struggling for durability, flexible circuits help change this as technology progresses. As organic light-emitting polymers (OLEDs) develop and become more widespread, expect more durable foldable cell phones. In the future, individuals will be able to see televisions that can wrap around the walls of their houses, in addition to cell phones (Watkins et al. 2021; Delta Impact 2021, Global Electronic Services 2021). OLED TVs will grow more popular, offering consumers a smaller and more versatile alternative to traditional LCD TVs.

2.23 Healthcare Analytics

The technique of examining past and current industry data to forecast tendencies, increase accessibility or even effectively control disease spread is known as healthcare analytics. The area covers various sectors and offers both international and micro viewpoints. It can point the way to better patient care, clinical data, diagnostics and corporate management. When paired with marketing intelligence suites and visual analytics, healthcare analytics help managers make more informed decisions by providing real-time information that can support choices and provide valuable insights. Healthcare analytics is a compilation of administrative and financial data that may help hospitals and healthcare managers improve patient care, provide better services and modernise existing processes (Sisense 2021). Wise decisions based on accessible data could help alleviate problems that can occur in traditional healthcare systems and ease the transition to value-based management. In their management systems, healthcare facilities are incorporating information technology. This system collects a significant amount of data on a constant schedule. Analytics supplies skills and strategies for extracting information from this complicated and extensive data and converting it into data that can be used to aid healthcare decision-making (Islam et al. 2018). Figure 2.61 repre-

Fig. 2.61 Applications of healthcare analytics

sents some of the usage areas and applications of healthcare analytics technology.

Healthcare data refers to any data about a person's or a population's health. To gather this information, healthcare providers, insurance companies and governmental organisations employ a variety of health information systems (HIS) and various modern tools, the combination of which can demonstrate a comprehensive picture of each patient as well as trends related to geography, socioeconomic status, race and propensity. The data gathered can be separated into distinct datasets, which can subsequently be examined. A number of tools are used to collect, store, distribute and analyse health data. Some of these methods are mentioned below:

1. Electronic health records (EHRs)
2. Personal health records (PHRs)
3. Electronic prescription services (E-prescribing)
4. Patient portals
5. Master patient indexes (MPI)
6. Smartphone apps

Every second, more and more healthcare data are being evaluated thanks to digital data collecting. A substantial amount of data is being collected in real-time as electronic record keeping, applications and other electronic means of data collecting and storage become more prevalent. There is a need for a centralised, systematic method of gathering, storing and analysing data so that it may be used to its full potential. In recent times, data collecting in health situations has become more efficient. The information might be utilised to enhance day-to-day operations and patient safety and predictive modelling. Both datasets can be used to track trends and generate predictions instead of merely looking at historical or present data. Preventative steps can be taken, and the results can be tracked in this manner (University of Pittsburgh 2021). Four main types of healthcare analytics are stated below:

- *Descriptive analytics* commonly takes the form of a dashboard, leverages historical data to provide insights into trends or benchmarks. While descriptive analytics can help understand what happened in the past, it can't give any substantial insight into how to affect future health outcomes or predict what might happen in the future.
- *Predictive analytics* employs modelling and forecasting to predict what will happen next. Although forecasting the future is beneficial, the conclusions are based on the premise that all conditions remain constant. Predictive analytics cannot be used to forecast what will happen after a specific intervention or modification.
- Machine learning technology is used in *prescriptive analytics* to recommend a course of action or strategy based on a variety of criteria. Prescriptive analytics can help you comprehend the consequences of a certain action; nevertheless, the inherent ambiguity and lack of maturity of this sort of analytics might lead to suboptimal decisions.
- Machine learning technology is used to examine raw data to find interconnections, patterns and outliers in *discovery analytics*. While discovery analytics aids to determine what is needed to investigate further, raw data can be incomplete or erroneous, limiting its utility (ArborMetrix 2020).

In recent years, there has been a significant trend towards predictive and preventative approaches in public health due to a growing need for patient-centric or value-based medical treatment. This is made feasible through the use of data. Rather than just treating the symptoms as they occur, clinicians can detect individuals at significant risk of acquiring chronic diseases and intervene before they become a problem. Preventive care may help to avert long-term problems and expensive hospitalisations, saving costs for practitioners, insurance companies and patients. If hospitalisation is required, data analytics can assist clinicians in predicting infection, worsening and readmission risks. This, too, can assist in lowering expenses and improving patient outcomes. In terms of epidemics, healthcare analytics analyses collected data in real-time to better understand the consequences of epidemics and predict future trends so that the spread can be slowed and future epidemics can be avoided (University of Pittsburgh 2021).

Pressures on healthcare institutions throughout the world to save costs, enhance coordination and results, deliver more with less and be more patient-centric are mounting. The growth of medical data systems, digital healthcare data and connected health equipment has resulted in an unparalleled information explosion, which has increased the industry's unpredictability. Nonetheless, the proof is growing that unsatisfactory medical outcomes and inefficiency progressively beset the sector. Developing analytic skills may assist such companies in using "big data" to provide meaningful insights, define their future vision, increase performance and save the critical time necessary to examine healthcare data. New analytics approaches may be leveraged to generate clinical and operational improvements to tackle business problems. Analytics in healthcare will progress from a conventional base point of transaction tracking utilising basic reporting techniques, spreadsheet applications and software reporting components to a prototype that will ultimately integrate predictive analytics, allowing companies to "see the future", provide more individualised health services, predict patient behaviour and allow for dynamic service (Cortada et al. 2012).

Healthcare providers are obliged to report on a variety of key performance measures. Proper data analytics are now a critical role for modernising digital healthcare software. It can increase productivity, manage daily operations and prepare for the future through trend analysis. An essential aspect is how healthcare analytics may benefit many stakeholders in the healthcare business (SourceFuse 2021).

As the ordinary adult lifetime rises along with the population of the world, data analytics in healthcare are prepared to make a significant impact in current treatment. The application of healthcare analytics can cut treatment costs, forecast disease outbreaks, avoid preventable diseases and enhance overall care for patients and standards of living. Data analytics simply digitises enormous amounts of data and then unifies and analyses it using particular technologies. With healthcare expenses surpassing expectations, the sector needs data-driven solutions. These solutions are beneficial to both healthcare experts and the industry. As more providers are paid depending on medical results, health companies have an economic incentive to reduce expenses while simultaneously enhancing patients' lives. Furthermore, because physicians' judgments are increasingly supported by evidence, studies and medical information offered by healthcare analytics are in great demand. Figure 2.62 shows the reasons for the importance of healthcare analytics technology (Kent State University 2021).

The healthcare industry has a history of being sluggish to react, yet it is in a unique position to benefit from data and analytics insights. The COVID-19 pandemic has emphasised the value of leveraging technology to improve efficiency in remote patient care and telemedicine. Given the popularity of virtual health, it is apparent that the healthcare sector will increasingly rely on AI and big data to fill in the holes in conventional healthcare systems. Instead of remaining just huge storage, the move to electronic health records in clinics has opened up the option of using data models to utilise this information to deliver proactive healthcare actively. As a result, the idea of a "data-driven physician" is gaining momentum (Tabata 2021). Healthcare analytics in the future will contain increasingly bigger datasets for healthcare companies to interpret and manage. As new technologies develop and customer desire for personal control grows, it will become increasingly vital to understand how to navigate the competitive landscape and scale patient's data to stay relevant. Leading hospitals are attempting to guarantee that data-generating technologies are utilised to produce the greatest outcomes for patients as data-generating technologies have spread throughout society and industry. The Internet of Things includes sensors that monitor patient health and machine status and wearables and patients' mobile phones. Because of the network of this equipment, physicians get a complete picture of what is going on in the hospital and may be informed in real-time if a data anomaly reveals changes that require immediate attention.

Fig. 2.62 Why healthcare analytics. (Kent State University 2021)

This drastic move towards data can help doctors make better judgments and, in turn, improve patient outcomes. Artificial intelligence and clever algorithms will evaluate healthcare data to improve medical practitioners' abilities, from picking which individuals to cure to the effective methods to guide them throughout assessment and treatments. These breakthroughs are changing the way the community views healthcare, culminating in healthier communities with extended lifespans (Huiskens 2020). The use of AI inside the forms of natural language processing (NLP) and machine learning (ML) can add a lot of value to delivering better outcomes across the existing healthcare continuum. The application of these technologies in healthcare will also aid in the development of new "value-based care" models, and with the rise of big data, it may be used to drive greater personalisation and transformation in healthcare analytics for patients. Aside from digital disruption, inventive start-ups have a unique opportunity arise and develop solutions that address specific challenges in the healthcare ecosystem (Saxena 2019). Also, the healthcare analytics market is expected to grow at a CAGR of 28.9% over the anticipated period, from an estimated USD 21.1 billion in 2021 to USD 75.1 billion in 2026 (Healthcare Analytics Market 2021).

2.24 Hydrogen

Today, increasing economic and environmental concerns increase the interest in alternative fuels. Hydrogen is one of the important alternative energy carriers' sources that are emphasised (Sazali 2020). Hydrogen is the simplest member of the chemical element family, which is flammable, tasteless, odourless and colourless and represented by the symbol H. This element is normally found in nature as a hydrogen molecule in pairs. Although hydrogen is widely found in nature, this element makes up only 14% of the earth's crust by weight. Hydrogen is not found alone in nature but as a part of the water in lakes, seas, glaciers and similar structures (Jolly 2020). Since hydrogen is not found in a pure form in nature, it must be produced.

Today, there are various methods for hydrogen production, but the four most well-known of these methods are given in Fig. 2.63. Electrolysis, steam methane reforming, direct solar water splitting and biological methods are some of the known methods.

In addition to the shared methods for hydrogen production, there are many more methods, and various classifications are made according to the environmental sensitivity of these production methods and the resources used for production. Three of these methods are widely known (Sazali 2020) and used. These are grey, blue and green hydrogen (Boykin 2021). In the grey hydrogen production method, natural gas (CH4) is the main material, and hydrogen production is carried out using auto thermal reforming (ATR) or steam methane reforming (SMR) methods. As a result of this production, CO_2 is released into nature. Due to this emission, this method is not environmentally friendly, and for this reason, it is called grey hydrogen production. In the production of blue hydrogen, the same methods as in grey hydrogen are used, and raw material (natural gas) is used.

However, in this method, the carbon dioxide produced due to the decomposition of natural gas is captured and stored. In this way, this gas that causes the greenhouse effect is not released into nature, and the harmful gases that come out during hydrogen production are largely eliminated. Although this method is more environmentally friendly than the grey hydrogen production method, it still has various effects on the environment since it is not possible to capture all the carbon dioxide that occurs during hydrogen production. Hydrogen that is produced by adopting and using the most environmentally friendly production methods in hydrogen production is called green hydrogen. The production steps performed in this production method are given in Fig. 2.64. The method used in this production method is electrolysis. The raw material used is water. Water is broken down into oxygen and hydrogen by electrolysis. The hydrogen obtained as a result of the separation is stored, and the oxygen, which is harmless to nature, is released into nature. Electricity is required for electrolysis, which is the method used in this production method. In this method, electricity produced by renewable energy sources such as the sun and wind is used to produce environmentally friendly hydrogen (Petrofac 2021).

Hydrogen can be used in different fields. These usage methods are shared in Fig. 2.65. Petroleum refining, chemical, stationary fuel cell, transportation and energy storage are the usage

Fig. 2.63 Hydrogen production methods and energy sources used in production

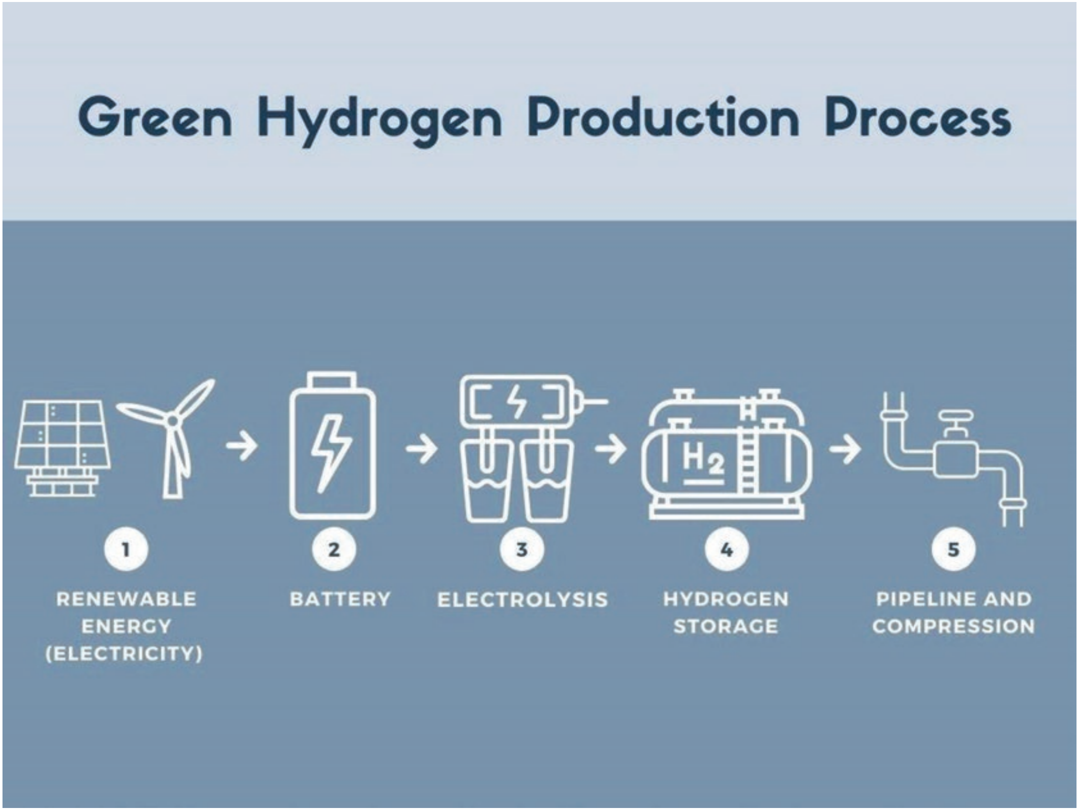


Fig. 2.64 Green hydrogen production

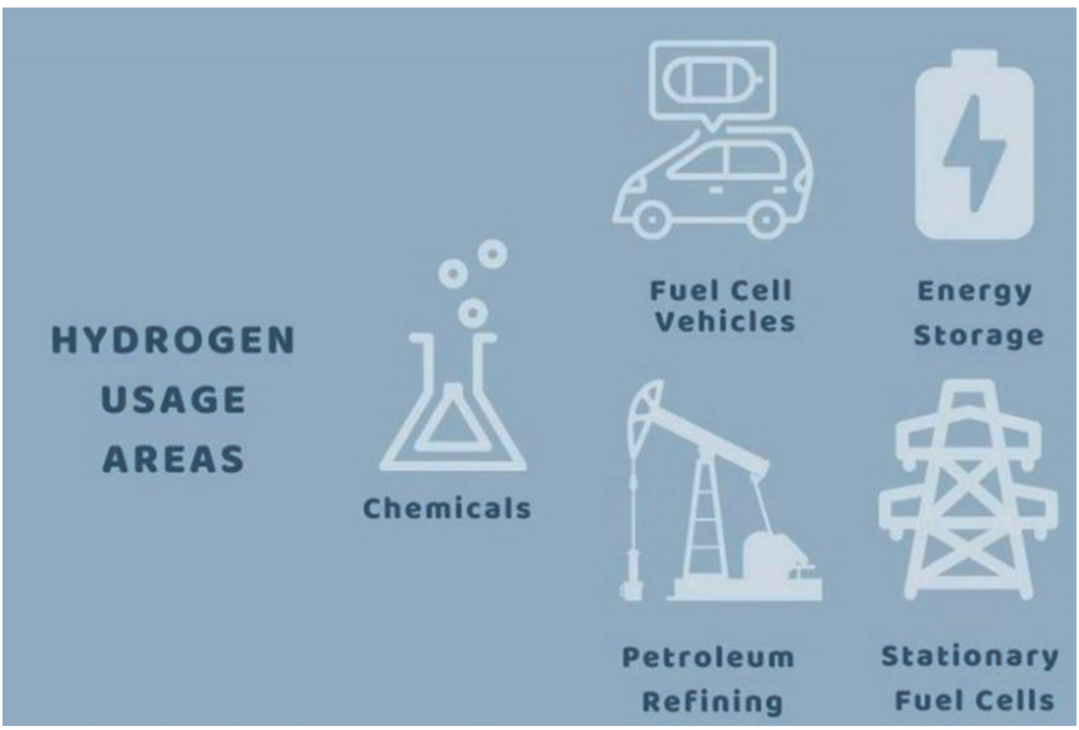


Fig. 2.65 Hydrogen usage areas

areas of hydrogen. Developments in transportation and energy storage appear as important application areas with the potential to increase the widespread use of hydrogen.

Hydrogen storage brings with it various advantages compared to other storage systems. For example, batteries can store certain amounts of energy for a certain time, and long-term energy storage is not possible in these systems. Here, the long-term storage feature of hydrogen storage systems comes to the fore. Depending on the size of the hydrogen storage facility, it can be stored and can keep the amount of hydrogen stored for days or even weeks after the storage process so that there is no storage-related loss during energy production. Although another storage system is pumped water storage systems that do not have various problems in terms of storage time or amount of stored energy, they require large lands and large constructions and are required to be formed in desired geographical conditions. In this direction, hydrogen storage systems also precede such storage systems (FCHEA 2021). Long-term storage is an important feature. These storage systems stand out as important candidates in emergency generators or other critical energy applications. The widespread use of renewable energy sources can bring along various problems. With this diversity in the sources of energy production, various problems can be experienced in ensuring the supply-demand balance in energy systems. These production imbalances experienced here cause the energy produced to be wasted if the production is more than needed or the system to be supported with fossil fuels due to the insufficient amount of energy being produced when the demand is high. In this case, energy storage systems gain importance. Hydrogen storage systems are becoming an important alternative at this point. These systems provide the needed power to the electrolysis machines when the energy need is low, hydrogen production is carried out and electrolysis machines can produce green hydrogen. This hydrogen produced can be stored, transferred to stationary fuel cells for power generation, transferred to fuel cell vehicles for use in transportation, transferred to these pipelines to reduce the carbon density in natural gas pipelines, or for later use as a cryogenic liquid, compressed gas (FCHEA 2021). When an energy system needs the energy, stored hydrogen can be used for electricity production.

Another area where hydrogen can be used is in transportation systems. Here, in these hydrogen fuel cell vehicles, the vehicles still work with electric motors, but at this point, unlike the battery electric vehicles used today, they are systems that produce their electricity. In other words, these vehicles do not meet their energy needs from an internal battery that can be charged externally, as in electric vehicles. Thanks to the fuel cells they contain, these vehicles effectively have their efficient power plants. By using this fuel cell technology in vehicles, the reverse of the electrolysis process used to produce hydrogen is applied. Thanks to this reverse electrolysis, the hydrogen taken from the tanks react with the oxygen taken from the environment. As a result of this reaction, water vapour comes out of the exhaust and electricity is produced. These vehicles are vehicles that operate without causing emission problems, just like electric vehicles. In addition, while long charging times in electric vehicles are a problematic issue, these vehicles can be charged in a short time, and this problem is significantly eliminated. Therefore, this technology constitutes an important alternative for the future (BMW 2020).

As it can be understood from these two usage areas, fuel cells gain importance at the point of conversion of stored hydrogen into electricity. Fuel cells are devices that produce electricity via an electrochemical way. The components situated in fuel cells are anode, cathode, electrolyte and circuit. Chemical reactions occur in anode and cathode; moreover, hydrogen is used as a fuel while oxygen is used as an oxidant. The working procedure of the fuel cells are very similar to a battery; however, if the fuel is available, the heat and electricity can be obtained without problems such as recharging against battery systems. The fuel and oxygen are inserted into the system at the anode and cathode sites, respectively. Electric energy and heat are produced during fuel cell activities. The electrons go through the circuit, whereas the protons are transmitted through the electrolyte membrane (Behling 2012). The electron movement can be designated as current. At the anode, the splitting of the hydrogen into electrons and protons takes place. As a by-product, water is emitted by the reaction that is carried out by combining protons, electrons and oxygen at the cathode site (Behling 2012).

Hydrogen can be used as a stationary and portable energy transfer source. This source is an energy carrier with great potential for clean and efficient power. Hydrogen energy is an important candidate for energy security, reducing oil and natural gas dependency, reducing greenhouse gas and air pollution. In addition, it is an important alternative fuel source for land or air transportation (Smith 2016). It contributes to the solution of the problem of supply-demand balance, which is in front of the storage of hydrogen and the transfer of energy thanks to hydrogen and the use of renewable energy sources. Since these systems can provide long and efficient storage, they become more advantageous systems than normal short-term and low-efficiency storage systems. Thanks to the storage of green hydrogen, which is produced using renewable energy sources such as the sun and wind, energy storage can be realised. In this way, when excess supply occurs in the supply-demand balance, the excess energy that has been produced can be stored. Hydrogen storage systems provide long-lasting energy storage. In this way, when energy is needed, hydrogen is converted back into electrical energy and an energy supply is provided. By using this storage method, the problem of not being able to reach the energy when needed, which is one of the negative aspects of renewable energy sources, is eliminated. In this way, when energy is needed, instead of preferring the use of fossil fuels to ensure energy balance, the use of stored green hydrogen can be used to prevent CO_2 emissions that may arise from energy production. In this way, energy is produced and used more cleanly. Hydrogen technology is emerging as an alternative that can be used in the field of transportation, and with its contributions in this field, it can contribute to reducing the use of fossil fuels and reducing CO_2 emission values. Today, electric vehicles are increasing day by day, but charging time is still an important problem in these vehicles. Since hydrogen vehicles provide an important alternative for this existing problem thanks to their short filling times, they stand out as an important option for the dissemination of such environmental-friendly vehicles in transportation. In this way, it can be an important solution for the environmental pollution problem caused by the transportation sector by increasing the environmental transportation options.

The reason why hydrogen attracts so much attention today is because of this low carbon emission. If hydrogen is used in energy transfer, it does not cause carbon dioxide emissions as in fossil fuels. When hydrogen is consumed, only heat and water are produced (Clark 2012). Although hydrogen seems to be such an attractive source, its usage areas are limited today and it is used in a limited way, especially in projects that can contribute to the environment. Today, the amount of hydrogen widely used in the petroleum and chemical industries is approximately 80 million tonnes. The amount of hydrogen produced is expected to increase to 100 million at the end of this decade and 500 million by 2050, especially with the development of technologies such as energy storage and hydrogen transportation. At this point, it becomes an important economy with the expected growth in the field of hydrogen. Today, 95% of the hydrogen produced is produced as grey hydrogen. In other words, fossil sources are used in the production of hydrogen (Schnettler 2020). The main reason for this is that this method is much cheaper than green hydrogen production. Grey hydrogen production costs are 1–2 Euros per kilogram, while green hydrogen production costs are 3–8 Euros per kilogram in Europe and 3–5 Euros in regions such as the Middle East, Russia, the USA and Africa. For this reason, grey hydrogen is a much-preferred source. However, with the increasing awareness about the environment, the demands and policies for green technologies are increasing. Efforts are also being made to reduce green hydrogen production costs. In the future projections, it is predicted that the green hydrogen production costs will decrease by half by 2030 and the kilogram cost of green hydrogen will decrease to 1–1.5 Euros by 2050. With the arrangements to be made and the technological developments to be experienced, it is foreseen that the hydrogen economy will turn into a green hydrogen economy and hydrogen production will increase rapidly, especially after 2030 (Van Hoof et al. 2021). At this point, although hydrogen is an important energy-transportation alternative for the future, it also has important economic potential.

2.25 Internet of Behaviours

The increase in the accuracy of analysis studies that can be done from existing sources and the expansion of their scope has allowed many different technical disciplines to emerge thanks to the development of technology. One of the technologies that can be mentioned in this context is the Internet of Behaviours (IoB). IoB can be defined as studies on data to provide information on user behaviours, interests and various possible preferences (Techvice Company 2021). While the Internet of Things (IoT) technology deals with the interaction of electronic devices with each other, IoB combines location, face and various preference information obtained from users and tries to match this information with various behaviours (International Banker 2021).

The starting point of IoB is to create an optimum level of choice with the integration of data obtained by electronic devices providing data exchange over the Internet with IoT (Todaro 2021). To achieve the integration mentioned here, data can be collected and processed from various sources such as customer information, social media, location tracking and citizenship data provided by government agencies (Techvice Company 2021). In this context, transactions related to IoB can generally be considered as a combination of behavioural science, data analytics and technology (Tech The Day 2021). Today, the concept of IoB is used effectively in several areas. These areas are listed in Fig. 2.66 (Pal 2021).

Consider Uber and its Internet of Things (IoT) application. It is used to keep tabs on drivers and passengers. A survey is done at the end of each ride to assess the passenger experience. They can go further by using IoB instead of IoT to collect data without needing to evaluate the experience through a survey. It is conceivable to monitor the driver's actions and then analyse the passenger

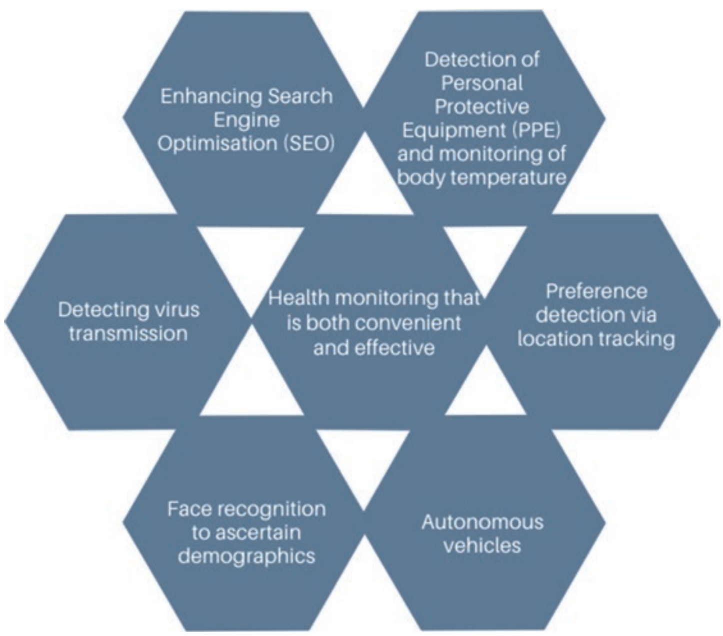


Fig. 2.66 Some usage areas of IoB technology. (Pal 2021)

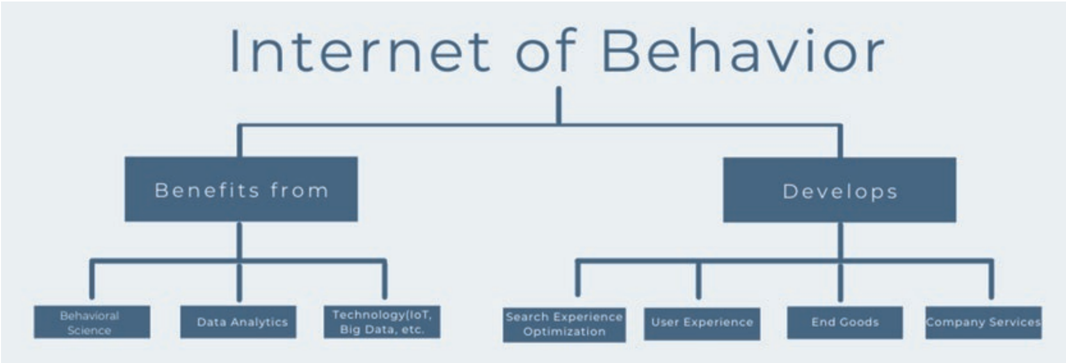


Fig. 2.67 Features of the IoB technology

experience to work on. Figure 2.67 demonstrates the features of the IoB technology.

The incorporation of IoT devices into many aspects of our lives does more than merely assist us in optimising and automating various procedures. It is profoundly altering sectors and ways of operation, including digital marketing. The importance of IoT technology and the IoB cannot be underestimated today, as they will have an impact on consumer behaviour and the marketing platforms used to capture their attention. So, it is critical to begin incorporating the IoB technology into the digital marketing plan of the business world as soon as possible to profit and obtain the greatest number of pleased consumers (Kolomiiets 2021). According to McKinsey, behavioural insights are key to unlocking an 85% boost in revenue and a 25% rise in gross margin. Businesses can utilise data to do behavioural analysis and establish where customers come from and what happens to them. Knowing this data via the IoB is crucial for analysing recommendations, constructing predictive models and developing effective methods to improve engagement, retention and conversion (Singh 2021). Furthermore, IoB integrates current technologies that directly focus on the person, such as facial recognition, location monitoring and big data. While some consumers are hesitant to provide their data, many others are willing to do so if it offers data-driven value. For businesses, this includes modifying their image, advertising items more successfully to their consumers or improving a product's or service's customer experience (CX). In theory, data on all aspects of a user's life may be collected with the ultimate objective of increasing efficiency and quality (Vector ITC 2021).

The biggest challenge that IoB technology will face is cybersecurity issues. Analyses made on people's data can be of great interest to cybercriminals. In addition, the sharing of this data by various companies due to commercial concerns is also a problem for personal security. The legal process from the past related to this situation should also update itself and make users feel safer (Techvice Company 2021). Apart from these problems, the free use of users' data is another issue that makes people prejudiced against IoB. This issue can be overcome by providing customised prices and services to individuals based on data obtained from individuals. The leading sectors that can do this are the banking and insurance sectors (personal interest rate, insurance pricing, etc.) (Kidd 2019). The advantages of IoB are schematised in Fig. 2.68 (IoT Desing Pro 2021).

One of Gartner's technological emerging trends is the IoB, which will enable this "plasticity" – or flexibility – and allow organisations to react, endure and even prosper during a crisis (Sinu 2020). IoB is still in its early phases, according to Gartner, but by 2025, more than half of the world's population will have been exposed to at least one IoB program, whether from the government or a private organisation. Furthermore, according to Gartner, by 2023, 40% of the global population's digital actions will be

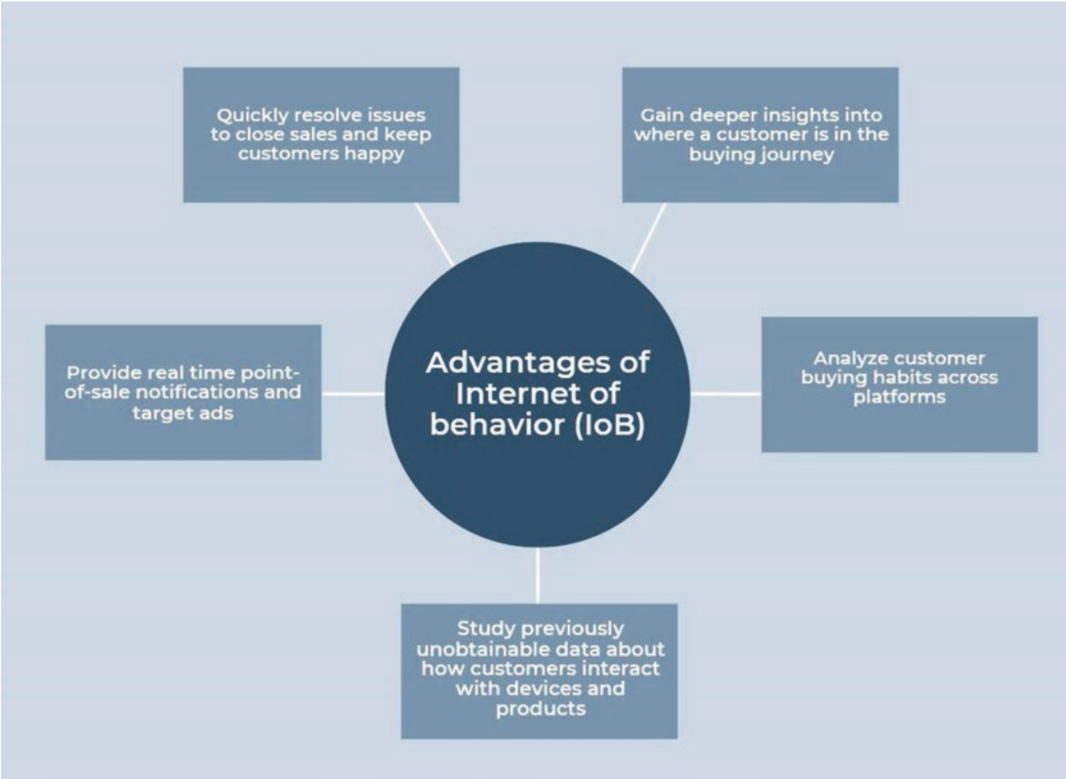


Fig. 2.68 Advantages of IoB technology. (IoT Desing Pro 2021)

tracked in order to affect human behaviour (Axios 2020). However, for these developments to take place, this technology must be accompanied by a transparency policy that is as user-friendly as possible, protecting privacy rights. In addition, it is very important to protect the cybersecurity of this data as highly as possible (International Banker 2021).

To minimise negative customer reactions, it will be critical to keeping a balance between customised offerings and interference. Any firm that adopts an IoB strategy must ensure that it has robust cybersecurity in place to secure all of that sensitive data. In the hands of the right people and with the proper data protection regulations, IoB will play a significant role in the near future (Sayol 2021). In personnel management, it will be feasible to measure the quality of workers' work and analyse how much each department, division or particular employee contributes to the organisation's overall success. Managers in Europe and the USA are already preparing to chip their staff. CNN Business noted that CEOs in the west are optimistic about implants on their employees. A Citrix survey reports that these implants can replace cards, keys and more to increase productivity. Respondents believe that such technologies will be widely available by 2030 and will be incorporated into the IoB.

Intelligent VoIP systems can find keywords in conversations. There is a strong belief that it will be possible to analyse even more to gather information about one's verbal, paraverbal and nonverbal characteristics. These feats would facilitate the management of atmosphere among employees, which is especially important for organisations in which contact hygiene is essential, such as insurance, audit and law firms. These teams are highly vulnerable to negative effects that can be caused by a single toxic or depressive behaviour of one specialist. Using IoB technology can potentially revolutionise the fashion business. It can be selected as a customised outfit for a person using this modern technology. The idea of "fashion" may then just vanish.

New IoB technologies have the potential to revolutionise medicine. For example, during the Coronavirus pandemic, many individuals acquired a new term: saturation (the degree of oxygen saturation in the blood). This indicator is measured regularly by patients suffering from severe diseases. Wearable devices, such as smartwatches, will almost certainly learn to monitor them fast as well. The same may be said about other appliances. Subcutaneous chips, for instance, will arise that record the temperature of the human body, the quantity of sugar in the blood, the number of leukocytes in the blood and other data. Also, humanity is moving closer to the day when the patient's medical data will be transmitted in real-time to the attending physician, regardless of where the patient is on the planet. The treatment will get more distant and objective (Sannacode | Web & Mobile App Development 2021).

2.26 Internet of Things

The Internet of Things (IoT) connects the virtual world with real-world physical activity. The fundamental idea behind the Internet of Things is to create an independent and secure connection that allows data to be shared between physical objects and real-world applications (Chopra et al. 2019a). The Internet as we know it today has expanded into the real world, embracing ordinary things that characterise the IoT concept. As we know it today, the Internet has expanded into the real world, embracing ordinary devices that constitute the Internet of Things vision. The components of the IoT vision include steady improvements in information technologies, microelectronics and communication technologies that we have seen so far, as well as their potential to continue into the foreseeable future (Mattern and Floerkemeier 2010). As the number of IoT applications grows, intelligent cars, smart cities, smart factories, smart homes, agriculture and energy as components of a broad IoT ecosystem are gaining greater consideration. More potential applications may be predicted by integrating similar technologies, technical methods and concepts (Vermesan 2013). As a result, IoT is envisioned as an ecosystem that grows to integrate surroundings and services better to satisfy better human life expectations (Lutui et al. 2018). The growth of IoT will dramatically increase Internet traffic by connecting numerous objects to the Internet. This will eventually result in increased data storage requirements. Privacy and security problems would arise as a result of such a huge network. To fulfil all these objectives, a suitable architecture is required. Although the IoT architecture is still being developed, it already has several characteristics. Business layer, application layer, middleware layer, network layer and perception layer are the five levels that make up this architecture. Figure 2.69 illustrates the architecture of an IoT system.

Artefacts of the physical environment and sensor equipment are included in the perception layer. Depending on the object's identifying method, these sensors might be RFID tags, barcodes or infrared sensors. This layer's primary role is to categorise things and collect information about them using sensor tools. This information on the object's position, inclination, humidity, velocity and orientation may depend on the type of sensor. The network layer's primary responsibility is to transfer information from the sensors to the processing unit reliably. This information can be delivered both wired and wirelessly. The middleware layer is largely in charge of managing service between IoT devices and apps. It can also communicate with the local datahub. It transfers information from the network layer to the database. This layer analyses the data and conducts computations regularly. Finally, it makes automatic judgments based on the results of the tests. Based on the object information processed in the middleware layer, the application layer offers global management of the whole program. IoT may be used to implement various applications, including smart homes, intelligent manufacturing and more. The business layer connects with the IoT network, which includes various apps and services. The business layer generates business models using information from the application layer (Chopra et al. 2019b).

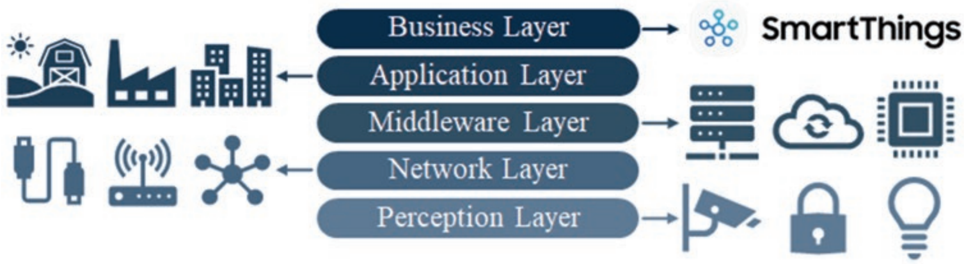


Fig. 2.69 Architecture of IoT

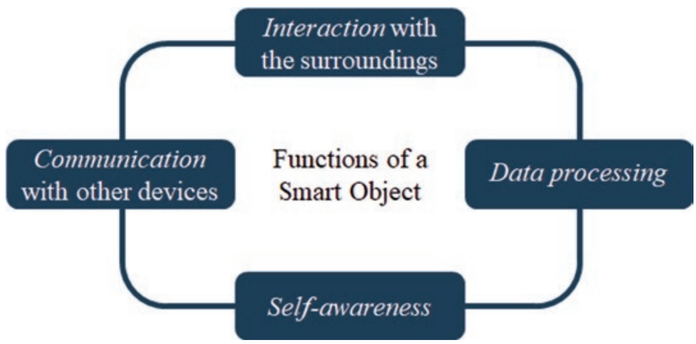


Fig. 2.70 Smart object functions. (Miragliotta et al. 2012)

As Fig. 2.70 articulates, an object is called "smart" if it achieves one or more functions: interacting with the surroundings, measuring or sensing environmental variables, communicating with other objects and central systems, processing the obtained data and performing self-awareness and localising.

Smart objects are devices that provide intelligence to IoT implementations and an interconnecting network and allow intercommunication of appliances. Properties of a smart network are depicted in Fig. 2.71.

Smart houses are a hot topic in IoT research. In other words, IoT and home automation are inextricably linked because all passive home electronics are becoming digital, wirelessly linked and capable of communicating over local networks or the Internet (Raj and Raman 2017). More capable and smarter appliances are the beginning of a smarter home environment. Real-time energy usage monitoring for all smart home equipment may considerably cut energy expenditures. In terms of smart security, combinations of alarms and sensors at the range of the property may immediately notify the police or fire department and homeowners. Second, by dividing the utilisation of IoT technologies in manufacturing into two categories: manufacturing and user experience, the use of IoT in the industry can be attested. Manufacturers utilise IoT to automate operations, track machinery and determine whether machines require repair. Furthermore, IoT devices in Internet networks are utilised to collect data from customers, which improves the user experience. Then it looks through the information it has acquired to see how it might improve the outcome and possibly solve problems. Finally, IoT-enabled remote patient monitoring (RPM) might enable patients to be tracked while at home. Caregivers can perform the first-step medical check-up without considering the distance, using data of the wearables that collect data of subject's vitals (e.g. blood pressure) (Greengard 2015; Hassan et al. 2018). Fourth, the Internet of Things (IoT) is an initiative to introduce smart city applications that use prevalent sensors in municipal infrastructures to provide real-time data (Latre et al. 2016). To meet the needs of urbanisation, energy management, transportation, health, governance and other

Fig. 2.71 Smart network properties. (Miragliotta et al. 2012)

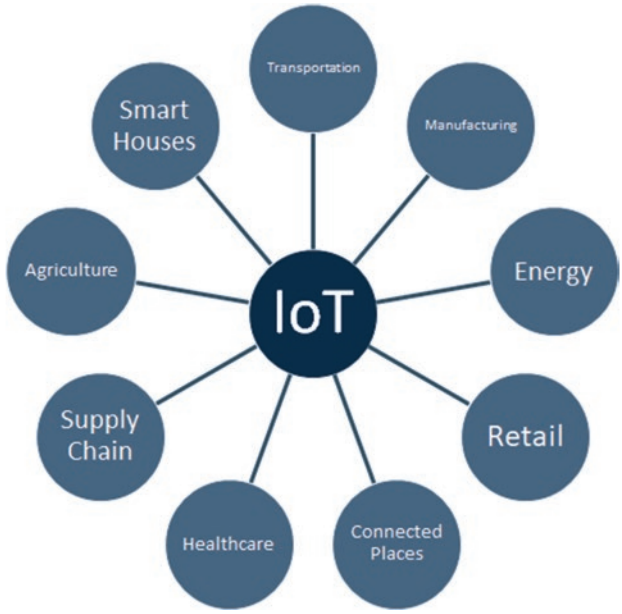


Fig. 2.72 Applications of IoT

aspects of modern smart cities are all centred on sustainable and effective solutions (Ejaz et al. 2017). Finally, agriculture is one of the examples of IoT applications that are worth highlighting. Farmers and producers would benefit from incorporating the Internet of Things into their operations, as well as a variety of equipment or gadgets that obtain and convey data through cloud services, because it would give them more choices to settle on, cuts costs and increase production efficiency (Namani and Gonen 2020). IoT applications may be found in a variety of settings, as shown in Fig. 2.72.

The demand for efficient systems to regulate and optimise energy and resource use in homes, industrial and agricultural facilities is increasing. With the deployment of the IoT, potential opportunities for reducing resource consumption and boosting efficiency may be identified. In recent years, IoT technologies have presented an intriguing potential to develop sophisticated solutions for sensor devices, and Internet-based information systems are used to monitor and control energy consumption. With an adequate power management system, energy hotspots may be detected and energy production can be raised in real-time in proportion to their process (Chen et al. 2018).

Chen (2018) also proposed an energy monitoring and management framework for a machining workshop. Depending on the tasks of the machinery, unused auxiliary equipment can be turned off. To improve energy efficiency, real-time energy-focused planning can be used. Moreover, by tracking power consumption frequency in real-time, effective load balancing can be used to reduce energy consumption during peak times. The Internet of Things attempts to increase energy use visibility and comprehension by including smart sensors and smart metres into the system. Consequently, data on real-time energy use from complex systems may be easily gathered and analysed to help people or home automation make more energy-conscious decisions. By acquiring vast quantities of energy-related data in near-real-time, these types of solutions generate a great deal of knowledge. As a result, it is critical to plan ahead of time how to integrate these IoT energy monitoring devices into the overall energy management system for the environment (Shrouf and Miragliotta 2015).

Also, IoT is seen as a feasible technical option for tracking, evaluating and making quick decisions about infrastructure provision before it fails. A smart water management network could be imagined by integrating IoT across the whole infrastructure architecture. When IoT is fully integrated, the water tracking system becomes a smart entity capable of detecting and treating problems without the need for constant third-party monitoring (Ramakala et al. 2017). The control application can also provide a real-time summary of the recorded data and make recommendations for corrective action (Geetha and Gouthami 2016).

Conventional approaches may be combined with cutting-edge technology like the Internet of Things and wireless sensor networks (WSNs) to enable a wide range of uses in contemporary agriculture for long-term sustainable food production. New IoT technologies are addressing agricultural issues by boosting farm production efficiency, quantity, productivity and cost-effectiveness. This rapid adoption of IoT in agriculture and smart farming technologies is gaining momentum, intending to have 24/7 visibility into the health of the land and crops, equipment in use, storage conditions, animal behaviour, energy consumption and water usage rates.

The concept of collecting and storing all relevant data, analysing it and giving meaningful outcomes enables the Internet of Things to become a significant modulator of existing urban and rural life. We might argue that robots and people would become increasingly intertwined after the first industrial revolution due to the gradual blurring of their boundaries between them (Greengard 2015). The disappearance of these boundaries allows for the formation of greater direct or indirect ties between humans and nature. Air is a direct method to engage with the environment, and pollution is a major issue nowadays. Air quality data analysis may be used to monitor toxic gases and harmful particles such as carbon dioxide and soot generated by factories and farmlands (Patel et al. 2016). Following that, necessary measures may be implemented right away. The energy derived from nature is the most extensive sphere of human connection. Because of the massive amount of data and traditional home power networks, measuring, administering, pricing and monitoring the energy that appears in every aspect of a person's daily life is extremely challenging. IoT appliances have the potential to occupy a large field of home appliances on their own, but in a network with a lot of data and continuous processing, the system grows wiser over time and develops its intelligence. The expansion of the Internet's area and depth above and beyond human contact will affect people's lives in the future (Greengard 2015).

2.27 Natural Language Processing

Natural language processing (NLP) is a multidisciplinary field consisting of computer science, artificial intelligence (AI) and linguistics subfields. The study of NLP is concerned with computers' capacity to apprehend words from texts or speech as well as humans. Through the combination of language modelling, computational linguistics, statistical, machine learning and deep learning models, NLP aims to enable computers to comprehensively process language, recognising the intent and sentiments of speakers or writers (IBM 2020). Many languages and text-oriented studies such as translating between languages, building a database, extracting summaries or understanding text content can be performed using this technology (Allen 2003).

The goal of NLP researchers is to learn how humans comprehend and utilise language so that suitable tools and techniques may be developed to help computers understand and modify natural languages to execute the tasks they are programmed to do (Chowdhury 2003). During NLP, the sentence's grammatical structure and word meanings are analysed by breaking down the sentences at hand. This way ensures that the computer understands and reads both spoken and written text at the human level (Wolff 2021). Only if the source text is a speech is a phonological analysis used. This analysis has to do with the internal and between word translation of tone of language, which can convey much about a word or sentence's meaning (Banerjee 2020).

If the source text is written, tokenisation is used. Simply put, tokenisation is the division of large amounts of text into smaller pieces. This process breaks down the raw text into tokens to assist in understanding the context or developing the NLP model (Chakravarthy and Nagaraj 2020). Morphological analysis is a method that concerns the internal structure of words, often used for NLP; it refers to the process of decoding words based on their smallest meaningful units known as morphemes. Banerjee (2020) explains this process through an example phrase, namely, "unhappiness". In his words: "It can be broken down into three morphemes (prefix, stem and suffix), with each conveying some form of meaning; the prefix un- refers to "not being", while the suffix -ness refers to "a state of being". The stem happy is considered as a free morpheme since it is a "word" in its own right. Bound morphemes (prefixes and suffixes) require a free morpheme to which it can be attached to and can therefore not appear as a "word" on their own". An additional method used for NLP is lexical analysis, which refers to the process of determining and examining the structure of words through separation into smaller pieces such as paragraphs, phrases and words. A language's lexicon is a collection of words and phrases that make it up and when working with lexical analysis, lexicon normalisation is considered to be essential. Among others, stemming and lemmatization are considered to be the most prevalent approach to lexical analysis. Stemming is a rule-based approach that regards the elimination of suffixes of a word (e.g. "ing", "ly", "es", "s" and so on). Additionally, lemmatisation is a method that combines vocabulary (the prominence of terms in dictionaries) and morphological analysis and is used to define the root form of a word. Syntactical analysis refers to the investigation of words in sentences to discover the sentence's grammatical structure. The grammatical evaluation and relative arrangement of words in sentences are used to perform syntactic analysis parsing. The semantic analysis focuses on the interconnections between word-level meanings in a phrase to find probable meanings. Some individuals feel that the step determines the meaning, but all of the stages ultimately decide the meaning. In contrast, discourse integration regards texts as a whole, examining aspects that transmit meaning by linking component phrases. For instance, sentences are linked together or dependent on prior context. This can be illustrated by the word "it" in the sentence "It wasn't that difficult". According to pragmatic analysis, without being encoded in the text, extra meaning is read into it. This demands a comprehensive awareness of the world that includes understanding intentions, plans and goals (Banerjee 2020).

Figure 2.73 is a sample word cloud technique that is used to visualise the result of processed text data. The text data from this section of the book is used to generate the word cloud given in Fig. 2.73.

According to Jusoh (2018), Natural language user interfaces, automated text summarization, information extraction, translation software, questions answering platforms, speech recognition, text mining and document retrieval are all examples of areas where NLP is applied. Figure 2.74 compiles the applications of NLP that can be encountered in daily life (Tableu 2021).

NLP is a strong technology with numerous advantages, even though there are several limitations and issues on that. Table 2.4 demonstrates the advantages and challenges of NLP technology (MonkeyLearn 2021).

NLP is a set of techniques used to create a grammatical structure and semantic relationship, produce natural language and create an output that conforms to the rules of the target language and the data at hand (Reshamwala et al. 2013).

NLP has found great use across various fields. It may not be difficult to imagine the usefulness of this technology in business contexts, as it was shown in multiple cases. For instance, NLP can be used in business process management (BPM) to significantly reduce the amount of effort that is

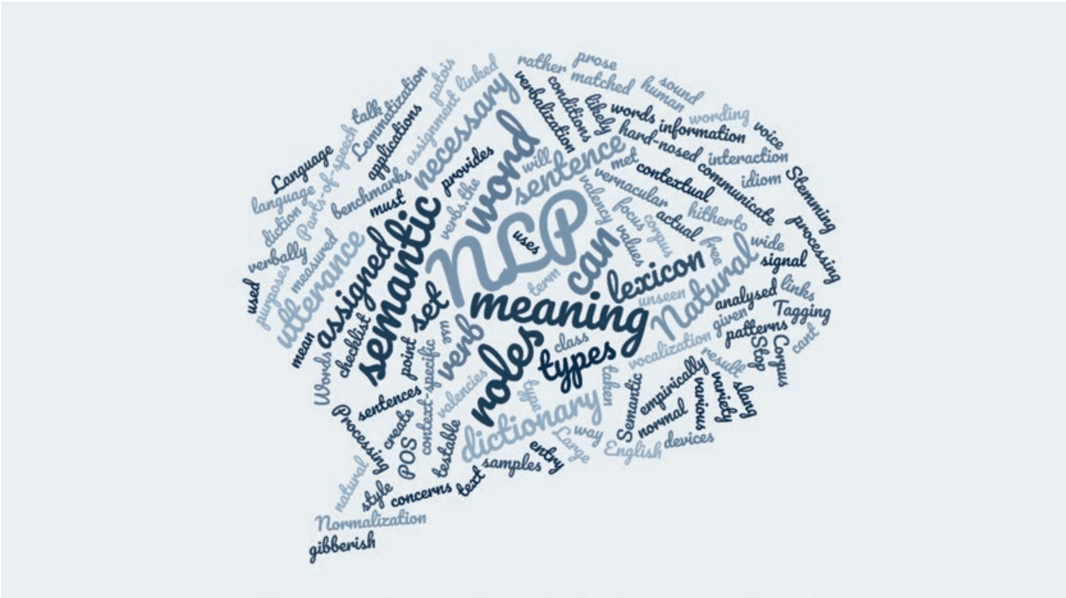


Fig. 2.73 A sample use of word cloud technique

Fig. 2.74 Some applications of NLP technology. (Tableu 2021)

required to ensure these processes work smoothly by enabling automation (van der Aa et al. 2018; Delicado et al. 2017). Furthermore, NLP can be used in human resources (HR) practices such as selection and recruitment. Analysing and screening applicants' resumes, responses and various other types of data with NLP allow for more efficient, less time consuming and less biased hiring processes (Talview 2018). However, NLP is an interdisciplinary technology, and its application has a great range, as demonstrated by its success across fields. For instance, Demner-Fushman and

Table 2.4 Advantages and challenges of NLP technology

Advantages	Challenges
Improved data analysis	Homonyms and contextual words and phrases
More efficient procedures	Faults in the written or spoken word
Better customer experience	Ambiguity and irony
Employees that are empowered	Research and development are lacking
Cost savings	Low-resource and domain-specific languages

MonkeyLearn (2021)

Simpson (2012) explain that, compared to the recent past, NLP techniques, which are used to analyse immensely large amounts of text data from biomedical literature, have been greatly improved and its promising results are a source of excitement in the field of biomedicine.

Furthermore, there has been increasing interest in NLP's application and use for sustainability. A recent report by Chakroun et al. (2019) underlines the importance of NLP in the context of sustainable development, which provides an exemplary use of NLP that contributes to the goal of reaching quality education. The example is of a chatbot that can successfully reproduce everything that a good teacher should do. In other words, it provides students with direction and support that is tailored for each student with the use of NLP. Another interesting application of NLP was demonstrated by analysing sustainability reports using NLP (Luccioni et al. 2020). Suggested by its developers, a custom model of NLP named ClimateQA was specifically designed to analyse, otherwise demanding, amounts of text from financial reports to detect segments that are of interest to climate change.

Additionally, NLP has found use in sustainable, responsible and impact investing (SRI), which emphasises the sustainability of organisations in three main categories called ESGs. Letter E stands for environmental factors such as carbon emissions, S stands for social indicators such as diversity and G stands for corporate governance factors such as bribery and corruption policies (Mukherjee 2020). These elements indicate the overall sustainability of a given organisation, and plenty of research indicates that there is a strong and significant relation between ESG's and financial performance (Morgan Stanley 2021; Whelan et al. 2020; O'Brien et al. 2018). To assess the sustainability of organisations, a considerably large amount of data from sustainability reports and articles has to be examined. This is where the use of NLP is highly efficient as it can analyse immensely large amounts of text data both from existing and live sources, mining for ESG related insights. NLP addresses various challenges of SRI by producing results significantly easier for interpretation, eliminates human error and the feat of including the most recent changes makes for a better, more efficient and up to date approach to SRI (Mukherjee 2020). Applications of NLP include, but are not limited to, the aforementioned examples across numerous fields such as biomedicine, psychology, business, finance and economics, all underline its usefulness and effectiveness in the automation of analytic processes.

NLP is a challenging problem of AI today. The biggest reason for this difficulty is that human language always contains semantic breadth and uncertainty. In studies conducted in this context, difficulties are usually encountered at the lexical and structural levels (Jusoh 2018). However, the increase in the amount of text data available every day and the potential to be used in other applications will make this technology even more important. Large volumes of unstructured, text-heavy data must be analysed efficiently by businesses. A great majority of the data created online and stored in databases is made up of natural human language. Until recently, businesses have not been able to utilise it properly. However, NLP can assist them in making efficient use of the largest available data (Lutkevich 2021). The mere fact that NLP is used even in the digital marketing industry is an indication that this technology will take a more important place in our lives (Lee 2019).

One of the greatest challenges to NLP stands to be code-mixed language, which refers to altered forms of language possibly unique to certain locations such as urban areas (Markets and Markets 2021). This limits the accuracy and efficiency of NLP processes with possible changes to normal meanings of sentences; thus, its application among various fields is also limited.

There has been a growing interest in automation and the facilitation of hiring processes among organisations and researchers. Personality is one of the most significant indicators, even more so than cognitive ability, of many work-related outcomes such as job performance, as established by a growing body of research (Barrick et al. 2001; Judge et al. 2013; Chiaburu et al. 2011; Salgado 2002). NLP methods have a highly promising future in its application to assess personality through numerous types of data, which can come from various sources such as job interviews, resumes and more, which in turn can be used to predict important job-related outcomes (Campion et al. 2016; Andrew 2021; Hickman et al. 2021).

Finally, regarding its financial future, there is a great expectancy of exponential growth in the market of NLP. Forecasts predict that its market share will exceed over 43 billion US dollars in 2025, an enormous increase of 14 times the size in 2017, estimated to be around 3 billion US dollars (Liu 2020). Additionally, the costs of commercial NLP solutions are considered to be high and may not be very tempting for smaller businesses and instead appeal to advanced programmers (Nadkarni et al. 2011). However, costs are expected to decrease in the future due to the increase in demand. This would facilitate the commodification of NLP (Markets and Markets 2021).

2.28 Quantum Computing

Quantum computing is a recent and emerging technology that uses subatomic particles during the computation process through a specific device called a quantum computer. The first question in this technology began when Feynman asked, "What kind of computer are we going to use to simulate physics?" He saw that classical computers are impossible to simulate the physical world. Because of the simulating time, the computers were not making a simulation. They were making only imitations. He asked at this point "Is there a way of simulating it, rather than imitating it?" in the space-time view. The answer to his question is superposition and entanglement in twenty-first-century technology, although this was unknown when Feynman was considering these questions. Therefore, nowadays, these questions give rise to the starting steps of quantum computing. It is understood that quantum mechanics can simulate the physical world with quantum machines (Feynman 1982). A "bit" is formed in classical computers to process and transfer data. It can be either "1" or "0". Bit 1 corresponds to an electrical signal in the wire, whereas bit 0 does not correspond to any electrical signal. In quantum computing, characteristics of quantum mechanics are utilised in expressing and processing the information as quantum bits. Quantum bits are so small that they work with the physical properties of atomic particles like classical bits. Although quantum bits, aka qubits, are similar to classical bits, there is a major difference: qubits can be in both 1 and 0 positions at the same time. The calculation process, which is also called "superposition", also measures all possibilities, namely, positions, according to the size of the problem. Graphical representation of the bits and qubits can be seen in Fig. 2.75.

While analysing the probabilities of a problem simultaneously, it chooses the correct answer according to some mathematical operators. Thus, quantum computers are designed to solve the

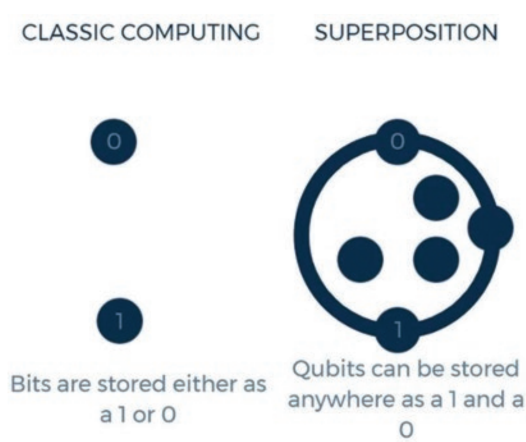
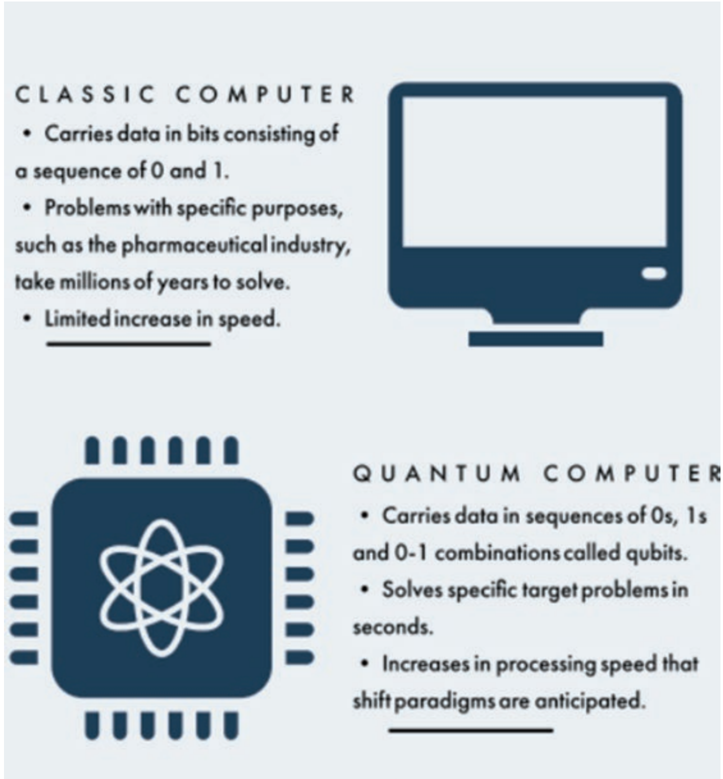


Fig. 2.75 Comparison of classical bits and quantum bits

Fig. 2.76 Comparison between classical and quantum computers



problems prepared for them in seconds. This makes the computation process much faster because 0 and 1 are not to be performed separately (Hughes et al. 2021). Figure 2.76 shows the comparison clearly. According to this, classical computational approaches, algorithms run on quantum computers can even reach exponential speedups. A quantum computer can operate at a cost that scales polynomially while operating on an exponentially large computational space thanks to certain features of quantum physics. Hence, quantum computing algorithms have the potential to make hard and time-consuming problems yielding and quickly solvable (Martonosi and Roetteler 2019).

Nature is surrounded by many quantum phenomena, such as Bose-Einstein condensation, which is a state of matter, superconductors and magnetic materials. As Feynman argues, it is often difficult for scientists to understand and simulate these materials because of the number of parameters needed to characterise a many-particle quantum system. It is mentioned before this part, a quantum computer can be used as a quantum simulator to simulate quantum systems way more efficiently than a classical computer (Eisert and Wolf 2013). According to Moore's famous law, the number of transistors located per square inch of an integrated circuit increases exponentially year by year (Moore 1998). If this trend somehow keeps continuing, the quantum effects will dominate in the computer components which are at the atomic scale (Eisert and Wolf 2013). Then, quantum computing will become nothing but a must ineluctably.

After this technology started to develop, some simulation problems can be solved as explained the following:

- While designing sensitive materials such as superconductors provide a better understanding of the material structure and its effects on the human body at room temperature.
- When performing the high-precision chemistry calculations needed to find alternative routes to the Haber process used in fertiliser synthesis in agriculture.

- When performing real simulations of dynamic molecules for increased accuracy.
- When examining problems with drug and molecule design (Maslov et al. 2019).
- Quantum computing offers better solutions for power grid optimisation for a country, more foreseeable environmental modelling development and discovering new materials.
- According to research, it is found that quantum computing could remarkably shorten the time spent performing calculations such as option-pricing and risk assessment (Sara Castellanos 2019).
- Daimler Mercedes-Benz is trying to develop a new battery for electric vehicles using quantum computing (Kanamori and Yoo 2020).

Based on the applications and examples given above, it is seen that the use of this technology is inevitable. Many big companies such as IBM, NASA and Google are quite interested and invest in this technology, which has promising future potential (Kanamori and Yoo 2020).

Researchers who deal with machine learning continuously use principal component analysis, vector quantisation, Gaussian models, regression and classification methods (Ho et al. 2018). It is assumed that quantum computing technology can be utilised to surmount vast amounts of data to yield better scalability and performance in machine learning algorithms (Perdomo-Ortiz et al. 2018). Since quantum computing offers reduced computational time, it may cause many applications of classical computing to evolve quantum computing applications. Robots that are used in drug discovery, logistics, cryptography and finance need to deal with large amounts of data. This creates a necessity for faster computation; as a result, quantum computing can be utilised to perform intensive computational tasks with less time required compared to the required time of classical computing (Buyya et al. 2018). In robotics, solving the problems related to kinematics, such as mechanical movement or unexpected behaviours against a command is challenging. It is expected that quantum neural networks or the other quantum computing algorithms will be able to handle these problems (Gill et al. 2020). Quantum computing is also expected to be useful in weather forecasting in the future. The computational power of the supercomputers that are used today is limited for some applications such as flood forecasting, urban modelling, sub-surface flow modelling and allied complex tasks. So, quantum computing algorithms can be adapted to solve such problems and achieve better Earth system models in the future (Frolov 2017). Quantum computing in the future in biochemistry and nanotechnology is expected to play an active role. With quantum computing, the results of biochemical processes are calculated faster than normal computers, and it is thought to play a role in the developments in the field of biochemistry in the future. Near future goals are listed in Fig. 2.77.

2.29 Recycling

Contrary to popular belief, products that have lost their function are not wasted. With the loss of product functions, the EoL stage begins. The end-of-life (EoL) phase can be defined in a variety of ways, such as when a consumer or operator disposes of a product without making any structural modifications (Gebremariam et al. 2020); making a non-functional product a reusable form of remanufacturing (Wang and Hazen 2016); recycling, which is the collecting and processing of discarded items as raw materials to create comparable products; with and without energy recovery, incineration and conversion of combustible wastes into gases; burying garbage or throwing it in a landfill ("EEA Glossary – European Environment Agency" 2021); otherwise, it simply results in a leak into the environment (Duque Ciceri et al. 2009). All items having an EoL date become trash. All stages of a product's lifespan are shown in Fig. 2.78.

In Fig. 2.78, the life cycle assessment (LCA) of products is shown. LCA is the most important instrument for determining a product's environmental impact. It is feasible to account for all of a product's environmental consequences using LCA, which covers all stages of the product's life

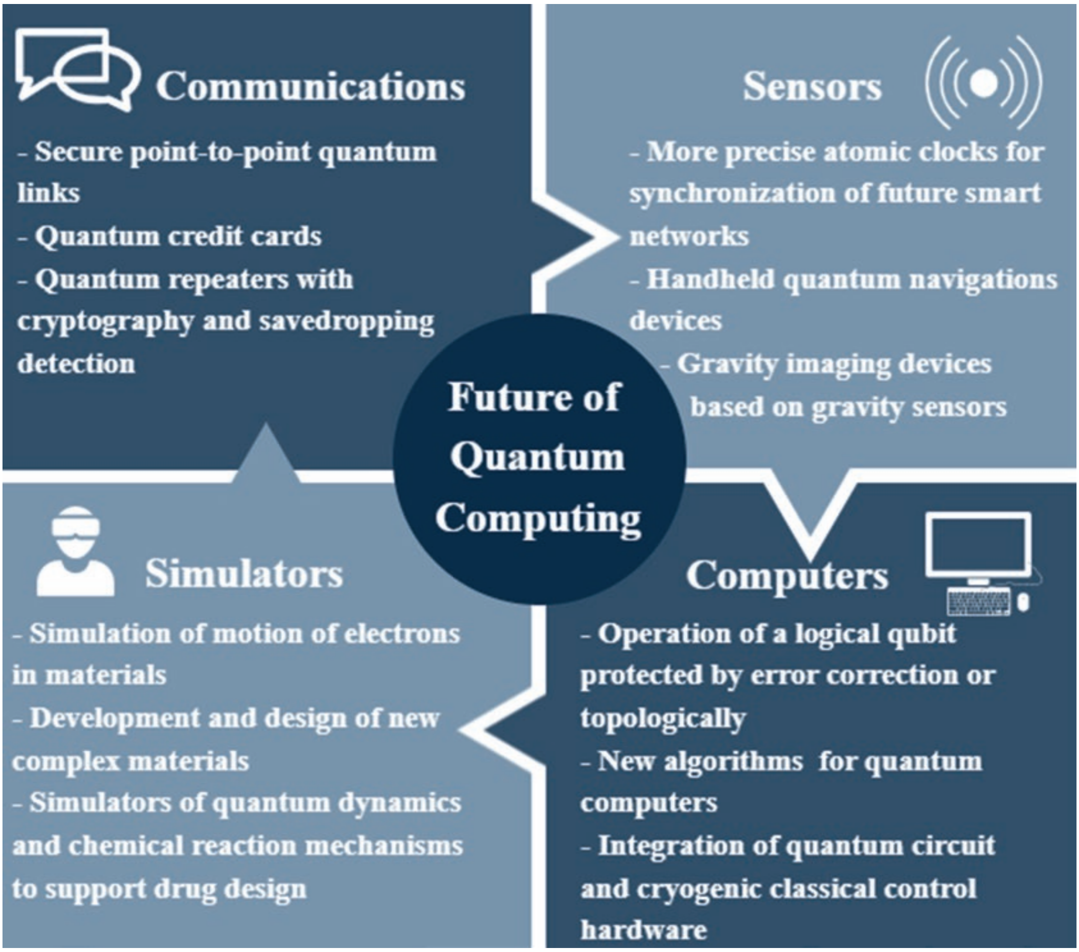


Fig. 2.77 Future of quantum computing

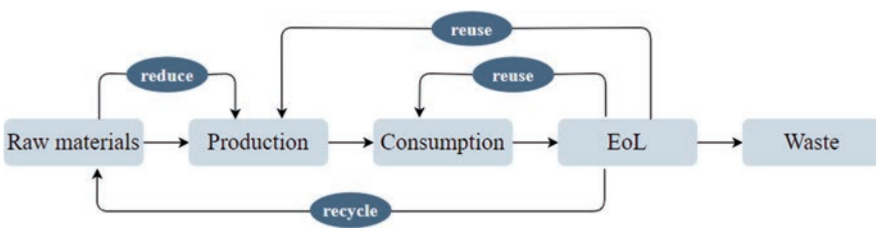


Fig. 2.78 General life cycle of products. (Spilka et al. 2008)

cycle, from resource extraction to waste disposal. The main principle of this cycle is based on the 3R principle. In Fig. 2.79, the main principles of waste management are explained.

According to these principles, preventing waste formation is the most effective and long-term solution to the waste problem. Secondly, products should be used in other possible means even after they complete their lifetime. After all this, recycling is a necessity. Recycling can be categorised according to the type of material released. Closed-loop recycling, in which the product produced from the material obtained as a result of the recycling of the EoL product, is the

Fig. 2.79 Principles of waste treatment

RECYCLING STAGES

INITIAL PROCESSES	SECONDARY PROCESSES
• Sorting and Seperation • Washing • Size Reduction • Pressing • Briquetting and Granulation	• Composting of Solid Waste • Combustion and Pyrolysis • Biogas Generation • Electrochemical Metals and Recovery

Fig. 2.80 General recycling stages. (Spilka et al. 2008)

same. The utilisation of recovered resources to create a new product is referred to as open-loop recycling. This results in either open-loop upcycling, which refers to the conversion of waste materials into something of more value and/or durability, or open-loop downcycling, in which the quality and usefulness of the resource is decreased or the capture of the material for future use (Dorn and MacWhirter 2016).

In Fig. 2.80, the recycling process is separated into two main stages:

Figure 2.3 shows recycling stages separated by the recycling stages as primary and secondary. Primary processes provide the appropriate situations for the actual transformation process that will begin in the secondary processes. Computer vision is used by artificial intelligence to map intricate material streams by analysing millions of photos. AMP neuron uses deep learning to improve the precise identification and categorisation of metals, plastics and paper based on their physical features, brand and other factors, as well as contextualising and data storage about each item it observes (“AMP Robotics” 2021). Waste may be used in a variety of ways in terms of technology in processing technology. In general, the initial stages are common, whereas the second stages vary depending on the EoL material. Five categories of secondary processes (Spilka et al. 2008; Vindis et al. 2008):

Chemical recycling: The process which alters the wastes’ chemical structure, such as fuel oil production from plastics.

Resources recycling is the degradation of the macromolecule; for example, hydrolysis and alcoholysis.

Biological recycling: The method delivers oxygen treatment, including solid waste composting and waste treatment without oxygen.

Thermal recycling: This method is used to describe waste items that are in the last stages of disposal.

Material recycling: This process aims to acquire material that is a high-value raw material for further processing.

The following are new technologies that have been created to improve the recycling process stages:

- Concrete: Advanced dry recovery (ADR) and heating air classification system (HAS) are technical methods of producing coarse-grained, fine-grained and ultrafine-grained fragments by recycling end-of-life concrete material. The ability to move these methods works favouring them to get installed near precast concrete manufacture facilities or directly into the area of demolishment. Generally, the important features of these methods have been increasing the greenhouse gases (like CO_2 and NOx) produced by transportation, helping to conserve the resources and utilise the sources more efficiently. These technologies offer a promising future to close the material loop completely and execute a circular economy in the construction sector (Gebremariam et al. 2020).
- Metal: A method to sort out the discarded metal by using a laser called laser-induced breakdown spectroscopy (LIBS) has been established by the Fraunhofer Institute for Laser Technology and Cronimet Ferroleg. The recycling process improved efficiency compared to earlier examples thanks to the recently developed detector. The method is created to handle high-speed steel alongside different materials too. High-speed steel objects could have cobalt in them, which is a highly valued alloy, and one could come across them in nearly every hardware shop, for instance, in gimlets or milling tools. LIBS is a method that can be used to differentiate at least 20 alloying metal types in tiny metal objects rapidly, automated and deprived of contact ("Laser-based sensor technology for recycling metals" 2021).
- Plastics: Today's technology like incineration, pyrolysis and mechanical recycling are technologies with high costs and not adequate in environmental and economic terms. The solution for this issue is collecting and processing plastic waste and producing more valuable outputs much more affordable and desirable. The new method is named low-pressure hydrothermal processing. It offers a process to make gasoline, diesel fuel and other valued matters out of the most frequent type of plastic, polyolefin, securely in the environmental and economic regards. A newly developed alteration method works on the combination of hydrothermal liquefaction with effective departure. When the alteration of plastics into oil or naphtha happens, it is proper to work as a reserve for different synthetics or to be torn into monomers, different types of solvents or various outputs ("pulp and paper mill waste becomes fish feed, energy and more" 2019).
- Textiles: Recycling and recovering old textiles and waste fibre materials through various procedures result in recycled textiles. Old or used textiles, tires, footwear, carpets, furniture and non-durable products such as sheets and towels are the most common sources of recyclable textiles in municipal waste. Recycled textiles minimise the demand for virgin resources like wool and cotton, pollution and water and energy use.
- Compared to virgin products, the cheap cost of recycled items is predicted to help the recycled textiles business grow overall. In 2019, the global recycled textiles market was worth \$5.6 billion, and by 2027, it is expected to be worth \$7.6 billion. Between 2020 and 2027, the market is expected to develop at a CAGR of 3.6% (Parihar and Prasad 2021).
- Paper: A group of Swedish scientists are using waste sludge from wastewater effluent treatment at pulp and paper mills to develop new biobased goods. Bioplastics, bio-hydrogen gas and fish feed may all be made from that organic waste. Over 20 experts are working together on processes that link material and economic flows important to fish farmers, Swedish pulp and paper mills and Paper

Province, the world's most important bioeconomy cluster. The goal is to provide advantageous market conditions for innovative biobased products and services (Brunn 2021).

- Lithium-ion batteries: Electronics, toys, wireless headphones, portable power tools, small and big appliances, electric cars and electrical energy storage devices all utilise lithium-ion (Li-ion) batteries. They can affect human health or the environment if they are not properly handled at the end of their useful life. Cobalt, graphite and lithium, which are all considered essential minerals, are used in Li-ion batteries. Critical minerals are raw resources that are economically and strategically vital to the USA, with a high risk of supply disruption and no viable replacements. We lose these important resources when these batteries are thrown away in the garbage (US EPA 2019).

The massive population growth in recent decades and the desire for people to embrace better living circumstances have resulted in a huge increase in polymer consumption, mainly plastics. The continued use of plastics has resulted in a rise in the number of plastics ending up in the waste stream, sparking a surge of interest in plastics recycling and reuse (Francis 2016).

The effect on the economy is explained through the plastics industry. The progress of the plastics sector reflected the so-called linear economy model, which emphasised the beneficial life of plastic items. This was true until the last decades. Growing environmental recognition at social and legislative levels has aided the adoption of the worldwide circular economy model (CEM) in the plastic sector in recent years. This model proposes that the plastic waste created after its useful life be recycled effectively and efficiently (Guran et al. 2020).

There are several advantages of recycling for an individual. First of all, recycling can reduce pollution. It can reduce the demand for new resources by recycling materials. This process may minimise the number of pollutants generated when creating new materials by using recycling methods. Secondly, it leads to lower costs. Recycling has an environmental as well as a financial point for companies. Working with recycled material is substantially less expensive than working with brand new material. For this reason, firms may save money by employing recycled materials. On the other hand, recycling is related to saving energy; since recycling materials saves a lot of energy compared to making new ones. With the increasing environmental awareness, it is beneficial for businesses to be seen as sensitive to the environment ("Advantages of recycling" 2021). These advantages are shown in Fig. 2.81.

Recycling can help eliminate the problem of large volumes of waste simply thrown into plants and still need to be addressed. Through recycling, in most cases, these incinerated wastes are recycled to combat global warming and air pollution. On the other hand, landfills and incineration sites have a very harmful effect on the environment that surrounds them. These sites can cause irreparable damage to animals' habitats. Through recycling, the need for these harmful landfills can be reduced by decreasing the amount of waste sent to them. In this way, especially animals in danger of extinction are protected. Moreover, recycling offers us a more environmentally friendly alternative to extracting raw materials from the soil. This helps conserve resources. So, recycling can help protect the world's natural resources for future generations ("Advantages of recycling" 2021).

Every year, humanity produces 2 billion metric tonnes of trash. According to global waste statistics, waste production would increase by 70% to 3.1 billion by 2050 if the current trend continues (Kaza et al. 2018). Also, the immensely increasing world population may speed up this period. Therefore, the 3Rs (reduce, reuse and recycle) have a significant role in preventing this problem and preserving the environment and natural sources. The success of the 3R implementation depends on the balance between the programs and policies at the local level. The essential points of action relate to governance issues, education and the awareness level of people and critical stakeholders. Other than these, techno-

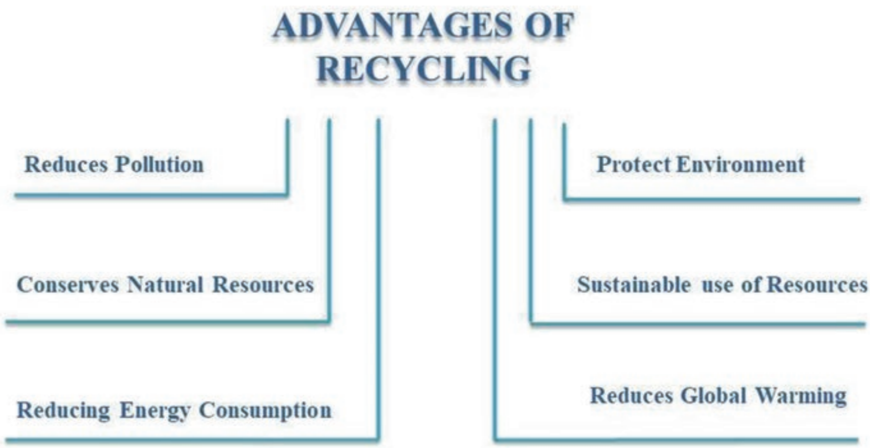


Fig. 2.81 Advantages of recycling

logical issues significantly affect that action to minimise the environmental impact while using technologies in the recycling step (Srinivas 2015). Automation will have a considerable impact on the recycling industry. In the coming decades, substantial developments may be expected to provide identification and separation processes more carefully than humans. Indeed, 62.6% of jobs in the waste management sector will become automated by 2030, according to a study conducted by PwC (2017). The recycling process will become much more effective and safer with advances in robot and automation technologies because fewer items are directed towards the landfill, and fewer people are exposed to hazardous waste items ("The Future of Recycling Services 2021). In terms of economy, the circular economy concept has grown in popularity, and it only takes a little effort to put it into practice. As manufacturers and recycling efforts collaborate and achieve critical mass, the future of recycling will see a rise in circular products. Once they are accomplished, they may become standard, with 100% closed-loop recycling systems assuring that recovered components are utilised in products of equivalent value to the original. Additionally, the future of the recycling sector depends on reducing the amount of the different substances recycled together and improving the quality of the raw materials obtained by the recycling process. One aspect of this future vision is standardising materials across products, which effectively reduces and redefines what we define as waste ("The Future of Recycling – Looking to 2020 and Beyond" 2020).

2.30 Robotic Process Automation

The most important debate in business and information systems engineering is which jobs will be done by humans and which jobs will be done by automation. This argument has become more critical as data science, machine learning and artificial intelligence have become widely used (van der Aalst et al. 2018). These technologies have shaped the structure of robotic process automation (RPA) solutions (Lamberton et al. 2017). The level of automation has risen by 75% in the factories since 1980, whereas in the office, automation has only grown by 3% ("Office 4.0 | RPA – the industrial revolution in the office" 2019). Because classical automation systems do not offer an effective solution for office work. In the classic system, the "inside-out" solution was used, but RPA provides an opposite solution, the "outside-in" approach (van der Aalst et al. 2018). RPA differs from other business automation systems in the following aspects (Willcocks and Lacity 2016):

- RPA does not affect the main system programming code because RPA operates over the top of the systems and accesses them via the presentation layer.
- RPA is about linking, dragging or dropping icons. Thus, RPA does not require software programming expertise.
- Data model or database is not important for RPA.

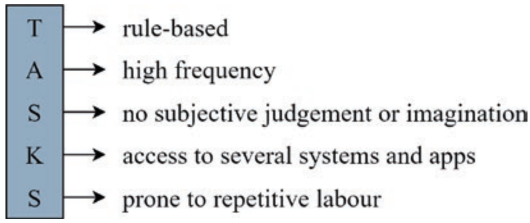


Fig. 2.82 Characteristics of RPA-appropriate tasks. (Fung 2014)

Even though the title "robot" refers to electromechanical devices, RPA is a software-based approach (Lacity and Willcocks 2016). For a better understanding, assume that there is a physical robot standing by the worker while the worker is doing a regular job performed as part of a process-related application, observing and learning about the job the worker is doing on the computer. The only difference from the robot is that it can perform this routine work with software without using computer hardware like a mouse or keyboard ("Robotic Process Automation (RPA)" 2021).

RPA systems use these key components which are (Tripathi 2018):

1. Recorder: It captures mouse and keyboard actions on the UI. The record keeping may then be replayed to repeat the same steps.
2. Extension and plugins: Several plugins and extensions are available on most platforms to make it easier to create and execute applications. RPA providers have created plugins and extensions.
3. Development studio: The robot configuration is created in the studio, and the robots are then trained there. In addition, robots are programmed with a set of instructions and decision-making logic.
4. Bot runner: This is what makes other components work and is called a "robot" and other components make it run.
5. Control centre: The management capabilities of the robot are provided at the centre by monitoring and controlling the operation of the robot.

Integrating automation into a process is costly. Figure 2.82 presents some of the RPA features that are needed to affect the business process positively.

If a process consists of tasks with these characteristics shown in Fig. 2.82, positive results are obtained when RPA automates this process. Also, RPA solutions differ for each business model as they should be designed for each company or industry according to their requirements (Madakam et al. 2019). So, a systematic approach is necessary to analyse the business model for RPA, and this approach consists of at least three main steps: proof of concept, pilot and leveraging. Firstly, the goal of an RPA is installation and identifying potential use cases inside the organisation. End-to-end processes and details are examined to find use cases. Depending on the process, it is seen for which parts of the process RPA can be a solution. At this stage, RPA use cases are established during the pilot phase. Procedures and technical requirements are completed. To ensure data flow, all necessary data must be in electronic form and missing data must be entered to ensure that the data is available. Also, the standardisation of data is essential. Lastly, the RPA system is tested at the leveraging stage. RPA is adjusted according to the tasks to be done. Once the procedures for usage and RPA have been determined, the RPA is then expected to be ready for use (Alberth and Mattern 2017). RPA office automation will perform effectively if these stages are followed carefully, and applicable areas are explained below:

- Business process outsourcing: RPA can replace outsourced workforce in business processes (Tripathi 2018).

- Insurance: Complex tasks in the insurance industry such as policy management can be accomplished with RPA (Tripathi 2018).
- Finance: RPA plays an important role in automating financial processes. Implementation of RPA provides efficiency and credibility (Tripathi 2018).
- Healthcare: Performing tasks such as data entry, patient planning, billing and cash flow by RPA increases the quality of healthcare (Rutaganda et al. 2017).
- Telecom: Tasks such as SIM swaps and order issuance are automated with RPA, providing time-saving, flexibility and scalability (Rutaganda et al. 2017).
- Manufacturing: RPA replaces FTEs (full-time employees), offering a more efficient and faster production process (Rutaganda et al. 2017).

RPA and other automation systems can automate various business processes of enterprises using structured data and specific business rules. With these implementations, the business hierarchy has changed and diamonds have replaced the triangle organisational model. This is shown in Fig. 2.83.

As explained in Fig. 2.83, the majority of the changes were in the medium portion of the market. The pyramid strategy is useful in terms of information storage, but it is also costly. The pyramid model tends to increase staff to fill skill gaps or expand resources. Robots are more flexible as they can more easily adapt to increases or decreases in service volumes. In the diamond model, SMEs and software robots work together to manage better processes that both require humans and are suitable for automation. The diamond-shaped enterprise needs more subject matter experts, quality assurance and management (quality/governance) to coordinate services with internal business units and RPA and business process outsourcing (BPO) providers (Willcocks et al. 2017).

RPA has positive effects on the business process if it is suitable for a business and the implementation steps are followed carefully. Several benefits of RPA are compiled in Fig. 2.84.

In Fig. 2.3, the positive effects of RPA are divided into three – on the company, the customer and the worker. RPA substantially boosts productivity while saving operational costs in terms of the company. Unlike workers, RPA can operate without any performance loss all day and is 15 times quicker than human beings (Engels et al. 2018). According to a Deloitte survey, after adopting RPA, the firm’s profitability has increased by 86%. Moreover, the quality of the work done has increased by up to 90% and the consistency of the work by up to 92% (*The*

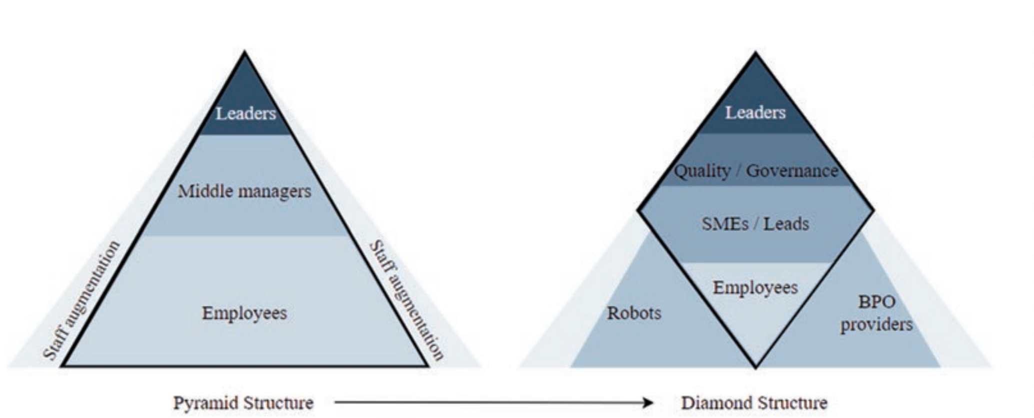


Fig. 2.83 Changing business hierarchy from the pyramid to diamond. (Willcocks et al. 2017)

Fig. 2.84 Benefits of RPA to companies, customers and employees

Robots are Ready. Are You? 2017). RPA prevents human error in an ordinary process, avoiding missing steps and greater data input accuracy. Also, customers can get service whenever they want, since RPA is available 24 hours a day (Alberth and Mattern 2017). Employees get rid of repeated work owing to RPA. Thus, they can devote their time to self-development, and they can take part in more important tasks in their firms (Axmann and Harmoko 2020). RPA has an important place in office automation.

RPA has some drawbacks, just like other technologies. Firstly, RPA implementation in the business model is costly. Also, many people believe that to benefit from robotic process automation, the end-user needs a lot of technical knowledge. This misunderstanding frequently hinders individuals from using the numerous advantages accessible to them. Moreover, fears that robots will replace humans and the distributive effects of RPA make it harder for people to adopt RPA. These disadvantages are due to a poor understanding of RPA (Sadaf et al. 2021). The main limitations of RPA ("The benefits (and limitations) of RPA implementation" 2017) include:

- RPA cannot read a non-electronic data source with an unstructured input. Use OCR (optical character reader) or demand for digital data as a solution to this problem.
- RPA will be problematic in terms of making RPA designs if there are variations in the format of the fields.
- Improvements (changes) in the process flow require a new design of RPA.
- RPA will not solve a faulty and inefficient process. Before using RPA, businesses should address the fundamental causes of their process or technological failures.

These present limits will not last indefinitely. RPA service providers will continue to attempt to eliminate these constraints to offer the leading product and participate in the RPA market (Axmann and Harmoko 2020). On the technical side, instead of being incorporated into an organisation's IT platform, RPA is located on top of IT (Aguirre and Rodriguez 2017). With the excessive accumulation of data in the business world and the evolution of new business processes, RPA will also be needed to automate processes that are not structured or not yet rule-bound. Businesses will be able to enhance quality, operational scalability dramatically and staff productivity with the integration of artificial intelligence and machine learning, due to big data and the cloud (Devarajan 2018).

2.31 Robotics

An autonomous mechanism capable of detecting its surroundings, doing calculations to make judgements and acting in the real world is called a robot. Typically, robots accomplish three things: detecting, calculating and acting. A sensor is used to detect its surroundings, a device that records, measures or indicates the physical properties and converts them into electrical signals. To calculate, robots can contain everything from a tiny analogue or digital circuit to high-performance multicore processor units. To act, some robots are built to accomplish certain functions, while others are more versatile and can perform a variety of applications (Guizzo 2018). Thanks to the major advancements in silicon-based chips and AI, some robots can even execute basic decisions. Ongoing robotics research is aimed at building self-sufficient robots that can navigate and make judgments in an unstructured environment. The study of robots is called robotics. Robotics is an interdisciplinary topic as it is an integrated mechanism that typically includes sensors, actuators and computational platforms on a single physical chassis. An advanced robotic system is composed of elements on several levels (Mckee 2006):

1. The fundamental physical core of the system is defined by the materials and mechanical systems, which include motors and gears.
2. The control and measuring systems that allow the robot system to function in stable conditions.
3. Electronic systems that connect sensors, actuators and controls with higher-level computing systems and incorporate lower-level intelligence.
4. Computational systems, which are generally based on a real-time operating system, provide a platform for high-level programming, multithreaded and concurrent operations, sensor fusion and sensor integration.

In Fig. 2.85, these four-level explanations are grouped as robotics' subsystems.

Developments in these subsystems help the use of robotics in various fields. These fields are shown in Fig. 2.86.

Healthcare and Medical Advances in robotics have the potential to revolutionise a wide variety of healthcare processes, including surgery, rehabilitation, therapy, patient companionship and everyday tasks. Robotic devices in healthcare are not intended to take over the tasks of healthcare professionals; rather, they are intended to make these tasks easier for them ("Top 5 Industries Utilizing Robotics" 2021). Medical robotics is one of the fastest-growing segments of the medical device industry, with applications ranging from minimally invasive surgery, targeted treatment and hospital optimisation to disaster response, prosthetics and home support (Yang et al. 2017). Rehabilitation robotics, which includes assistive robots, prosthetics, orthotics and therapeutic robots, has made the most extensive use of robotic technology in medical applications. People with disabilities gain more freedom through assistive robots by assisting them with daily activities (Hillman 2004).

Agriculture According to Bechar and Vigneault (2017), agricultural robots are sensitive programmable devices that perform a range of agricultural tasks, such as cultivation, transplanting, spraying and selective harvesting (Santos Valle and Kienzle 2020). Agricultural robotics aims to achieve more

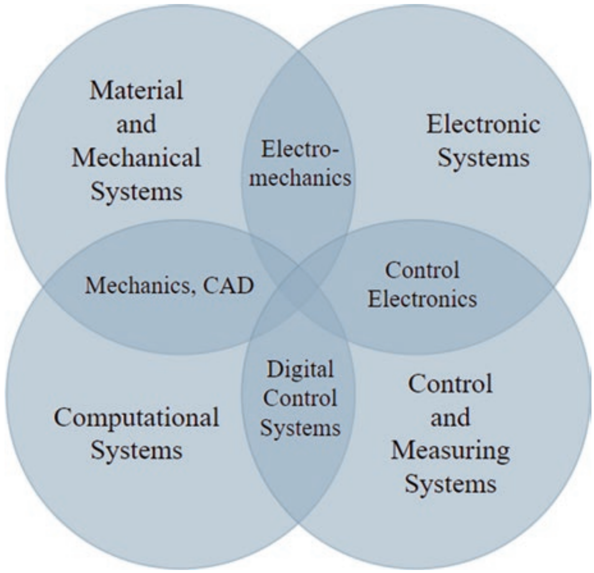


Fig. 2.85 Robotic subsystems

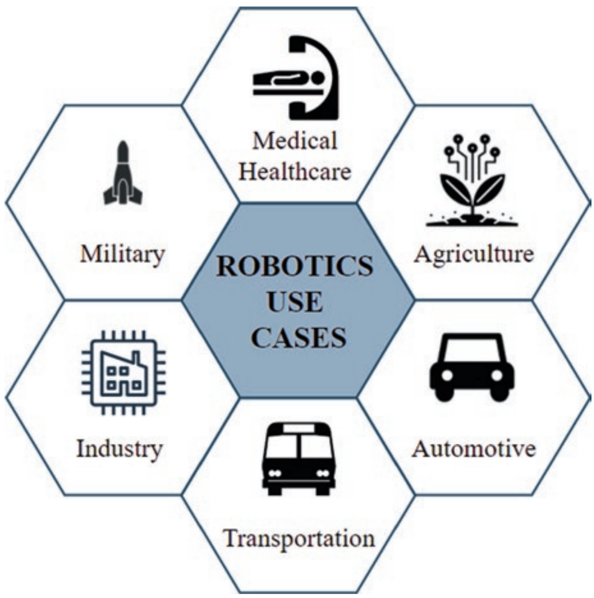


Fig. 2.86 Robotic use cases

than only the application of robotics technologies to farming. Most of the agricultural vehicles that are utilised for weed detection, pesticide dissemination, terrain levelling, irrigation and other tasks are currently staffed (Cheein and Carelli 2013). Agriculture evolved from a labour-intensive business to mechanisation and power-intensive production systems throughout the last century, and the agricultural industry has begun to digitise in the last 15 years. A constant labour outflow from agriculture occurred as a result of this transition, primarily from routine activities within the production process. Robots and artificial intelligence can now do non-standard jobs previously more suitable for human labour (e.g. fruit picking, selective weeding, crop sensing) at cost-effective levels (Marinoudi et al. 2019).

Automotive The automotive sector has been greatly influenced by advances in robotic machine vision technologies. Vehicle manufacturers and component suppliers are increasingly relying on 2D and 3D imaging to perform an expanding variety of quality assurance and assembly operations with increasing accuracy and complexity. As 3D systems become more commonly utilised and sophisticated, new applications will emerge, and demand for robotic systems will grow as the market becomes more competitive (Bogue 2013).

Transportation Transportation research committees are progressively coming around to the idea of using robots. A unique robotics tutorial session has been set aside for an upcoming conference on new technologies in transportation engineering. The synthesis of all robotics-related data to establish a complete knowledge base is the most critical short-term goal, which is mostly numeric, graphic and image data (Najafi and Naik 1989).

Industry Industry 4.0, also known as the fourth industrial revolution, is a new period in which industry will engage with technology such as robotics, automation and artificial intelligence (AI), among others. Robotics is becoming increasingly popular in industries around the world. More industrial robots are being developed using cutting-edge technology to aid the industrial revolution. Not only will intelligent robots take the role of people in basic organised processes in restricted spaces, but they will also take the place of humans in more complicated workflows (Bahrin et al. 2016). Precision and the ability to be reprogrammed for jobs of varying sizes and complexity are more important to these machines than speed. Robotic manufacturing technology is also becoming safer to employ. Robots can recognise and avoid people in the workplace thanks to cameras, sensors and automated shut-off capabilities ("Top 5 Industries Utilizing Robotics" 2021, p. 5).

Military Surveillance, reconnaissance, the detection and demolition of mines and IEDs as well as offensive and assault are all areas where military robots might be useful. Weapons are mounted on that last type of vehicle, which remote human controllers currently fire. Although there are many ethical concerns, unmanned ground vehicles and robotics in many areas are being developed rapidly in the military sector (US Department of Defense 2007).

However, many people think that their jobs may be replaced with robots, but the situation is not like that ("7 Advantages of Robots in the Workplace" 2018). Robots have generated new occupations for previously employed folks on manufacturing lines as programmers. They've shifted staff away from repetitive, tedious tasks and placed them in more rewarding, demanding positions. In the workplace, robots provide more benefits than drawbacks. They enhance the lives of current workers who are still required to keep operations operating efficiently while also increasing a business's chances of success. Robots have also grown increasingly prevalent across various sectors, from manufacturing to healthcare, as a result of robotics advancements ("Benefits of Robots" 2021). The advantages of robotics in these fields are given in Fig. 2.87.

The advantages of using robots in various fields are explained in three main titles: productivity, safety and savings.

Productivity Robots perform work that is more precise and of higher quality. They are more accurate than human employees and produce fewer errors. A robotic pharmacist at the University of California, San Francisco, fills and dispenses prescriptions better than people. There was not a single mistake in over 350,000 dosages ("New UCSF Robotic Pharmacy Aims to Improve Patient Safety" 2011). As robots do not require breaks, days off or holiday time, they can produce more in less time.

Safety Robots remove the need for workers to do hazardous jobs. They may work in unsafe situations, such as low lighting, dangerous chemicals or tight areas. Robots, for example, are assisting with the clean-up of Fukushima, a nuclear power plant in Japan that was destroyed by an earthquake and tsunami in 2011. The Sunfish robot-assisted in finding missing fuel within a nuclear containment tank (Beiser 2018). Furthermore, robots can carry heavy loads without harming themselves or becoming tired.

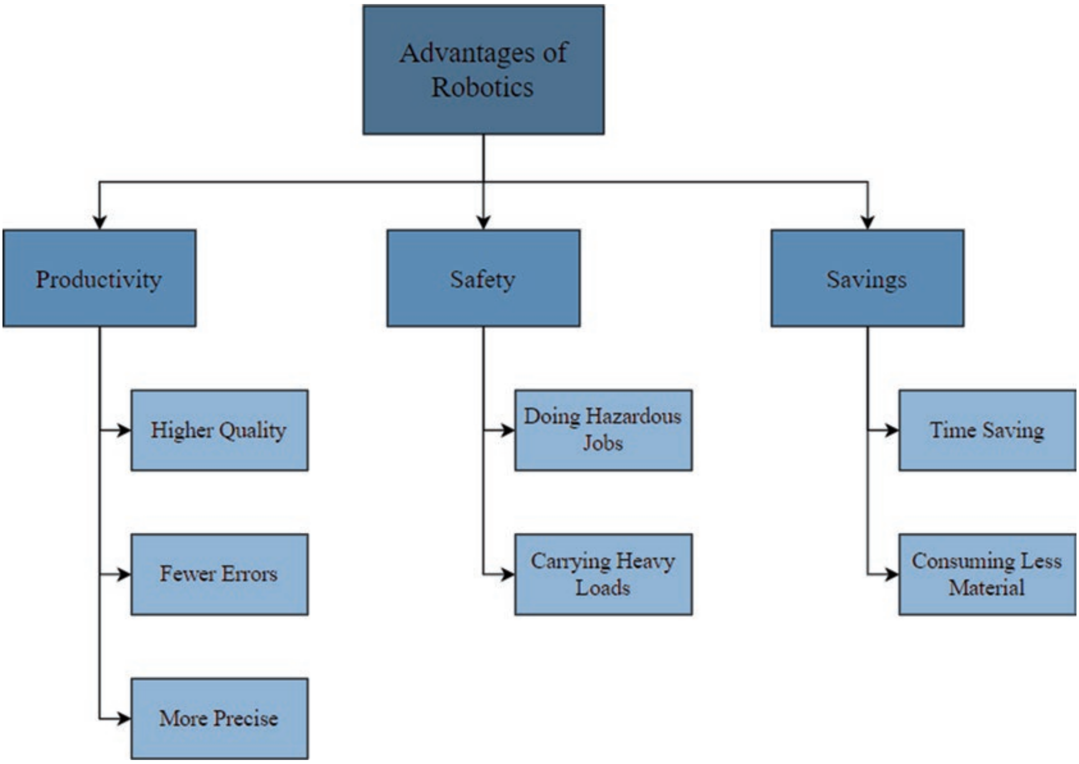


Fig. 2.87 Advantages of robotics

Savings Robots save time by producing more products in a shorter amount of time. Because of their precision, they also decrease the amount of wasted material. Robots save firms money in the long term by providing quick ROIs (returns on investment), reducing or eliminating worker's compensation and consuming fewer materials.

Robots have many more advantages apart from these. They also help businesses to remain competitive while maintaining jobs in the economy. As more industries use robots, the benefits of robotics continue to increase ("Benefits of Robots" 2021).

The number of robots has been exploited to such a degree that both the scientific and industrial sectors will be unable to absorb them, and we are about to approach a phase in which selection will be required (Pagliarini and Lund 2017). According to a study conducted by Oxford University, in the next 20 years, 47% of jobs in the USA may be automated (Frey and Osborne 2013). Additionally, according to 2021 robotics industry data, the number of robots used in the automotive industry is about 1290 per 10,000 employees ("US Robot Density in Car Industry Ranks 7th Worldwide" 2021). We can understand with this statistic, whether we like it or not, robotics will be a much more essential part of daily life. Sensors, motion control and machine learning advancements have increased the versatility of robotics and cognitive systems to unprecedented levels (Matthews 2019). Given the rapid advancement of robotics, now is an ideal time to consider what the future may hold.

1. *Artificial Intelligence Will Face Regulation*

Elon Musk has fuelled the fire by declaring artificial intelligence (AI) to be our "most existential concern" and comparing AI research to summoning demons (Palmer 2019). Although it can benefit humanity, AI will remain to be examined by those worried that robots will become more intelligent than their developers. Expect the fight over AI regulations to continue in the future and governmental or industry rules to arise (Worth 2016).

2. *Designers Will Move Away from Humanoid Robots*

Humanoid aesthetics will play an increasingly significant role in accepting new robots as they become more widespread in homes and workplaces. The "uncanny valley", a graph of emotional responses to a robot's resemblance to human appearance and behaviour, is a significant impediment to a seamless transition to a society populated by robots (Brenton et al. 2005). If humanoids are to become more intertwined with humans, more must be done to prevent uncanny valley. To make people more at ease with robots and make it simpler to engage with them, robotics developers will enhance semi-humanoid advancements that maintain essential human characteristics while also retaining conventional machine forms (Worth 2016).

3. *Aerial Robots Will Reach Widespread Adoption*

Safety concerns, efficiency and legislation have recently sparked much discussion about UAVs. Despite this, people and companies continue to experiment with unmanned drones in various ways, like lifeguards have flown them to keep swimmers safe throughout the summer months. However, there are concerns about the growing usage of that technology. A man from the USA attached a handgun to a consumer-grade drone and fired the gun remotely. While local authorities claim this type of drone usage is legal, the FAA (Federal Aviation Administration) claims it has laws prohibiting installing weapons on civil aircraft (Worth 2016).

The future of robotics will be reshaped with technological advancements and how society will react to these developments. Advances in robotics come with ethical issues. The ethical question will be critical and thoroughly explored in the future. On the other hand, experts have critical duties such as initiating discussions amongst specialists from diverse fields and developing rules for this area.

2.32 Soilless Farming

Until the year 2050, the estimated total number of inhabitants of the world will be up to 9 billion, and meanwhile, nearly half of the land suitable for farming might be useless. To fulfil the need for sustenance for this blooming number of people, the food products should be up to 110% more (Okemwa 2015). This increasing number of the population needs an efficient solution to manage their needs. Soilless farming methods like hydroponics could be a proper suggestion regarding this problem. Soilless farming can be explained as a way of breeding plants by using water to nourish the roots while using different mediums than soil. The plant's needed nutrients are fused into a water solution in proper density, called a "nutrient solution" (Oyeniyi 2018). The goal is to create an environment where the plant can grow properly without soil as a growing medium. When using farming methods such as hydroponics, the process is, simply put, making the plant meet the nutrients it needs by carrying them to the roots as a water solution containing the needed oxygen and nutrients ("Soilless Agriculture" 2021). Many sorts of yields can be grown hydroponically. Herbs such as rosemary, sage, oregano, basil, chive, celery, mint and lavender; vegetables such as cabbage, cucumber, potatoes, cauliflower, cabbage eggplant, lettuce, peas and asparagus; fruits such as tomatoes, watermelon, blueberries, strawberries, blackberries and grapes (Mohammed 2018). Different techniques of hydroponic configurations and systems according to the way of giving nutrients are shown in Fig. 2.88.

Soilless farming techniques in Fig. 2.88 are explained below:

The Deep Water Culture The deep water culture makes the roots of the plant float on the nutrient water constantly circulating (Elkazzaz

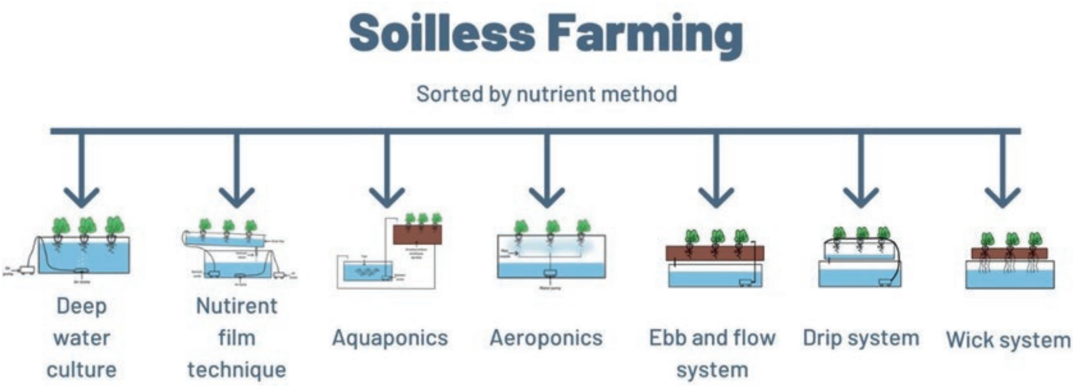


Fig. 2.88 Soilless farming methods according to the way of providing nutrients

2017). It is a method of growing plants on a floating or hanging support, such as rafts, panels or boards, in a container holding a 10–20 cm nutritional solution (van Os et al. 2021). The roots are dangled 6–18 inches into the nutrient water, which contains dense oxygen levels, to the time of harvesting. The deep water culture contains a large amount of water to balance inconsistencies in the saturation of the solution. In any failure in the pump mechanism, one would have plenty of hours fixing the pump without facing essential issues such as the roots not reaching the nutrients and water they need (Elkazzaz 2017).

Nutrient Film Technique (NFT) NFT is a hydroponic system based on sending nutrients to plants' roots by circulating water. The nutrient film technique system provides plants with an environment in which the plants are placed in a platform that is placed above the tank containing the nutrient solution in a slightly tilted manner. The nutrient film technique is focused on circulating the nutrient solution plants need to their roots through some routes such as pipes. The solution is contained in a tank, and through a pump, it is sent to pipes or watering equipment, and it turns back to the tank, constantly circulating (Elkazzaz 2017). For this technique, a level slope must be prepared, immune from depressions that could allow deep pools of the non-rotating solution to collect within a channel and multiple methods are utilised to achieve this (Spensley et al. 1978).

Aquaponics Aquaponics is a mutual system of plants and fish and their environments. Aquaponics consists of both aquaculture and hydroponics as symbiotic cooperation since the water used for the plants in the hydroponics system is also used for the animals living in the water tank of the aquaculture system. For aquaculture, the waste of the water animals should be expelled from the environment since the excrement is harmful to the animals due to the ammonia it contains. The aquaponics create a configuration where the water is purified by the organisms living in the roots of the plants, which are in the hydroponics, nitrifying the waste coming from the aquaponics systems and turning the waste into nutrients the plant can benefit from, therefore cleaning the water and circulating it back (Elkazzaz 2017).

Aeroponics Aeroponics systems work by sending nutrients to the plant by spraying a mist of nutrient water to their roots. Aeroponics is the method where the plants' hanging roots are exposed to a mist from the nutrient solution periodically; the main asset to this method is aeration (Modu et al. 2020). In aeroponics systems, the plants' roots are left dangling inside a cover where a powerful pump mists the nutrient solution and diffuses the solution to the entire root. Some aspects of aeroponics make it highly dependent on energy since the spraying mechanism is the most crucial part of the configuration. Since the roots constantly contact the air, they tend to be dehydrated very quickly if the pumping circle is disrupted (Elkazzaz 2017).

The Ebb and Flow The ebb and flow is a configuration that depends on initially surrounding the grow tray then discharging the nutrient solution to the nutrient solution tank and repeating this cycle. Generally, this cycle is regulated by a timer controlling a pump that is inside the nutrient solution tank. In regards to the type of plants, the heat and humidity of the environment and the kind of medium used for the plant to develop in, the daily periods of the pump are regulated (Dunn 2013).

Drip Systems Drip systems are most likely to be the most preferred kind of hydroponics worldwide. By a pump controlled by a timer, the nutrient solution drips to plants one by one thanks to a dripping pipe (Dunn 2013).

Wick System Wick system is the easiest type of hydroponic system. It doesn't have any parts that are moving and hence does not require any electrical types of equipment, including pumps. On the other hand, the wick is the link between the plant in the pot and the solution to nourish it in the existing reservoir. It is also beneficial in regions where electricity isn't available or is unstable because it doesn't require electricity to function. Plants are grown on a substrate in this method (Elkazzaz 2017).

Also, these systems can be designed by using two different methods according to the circulation of water as shown in Fig. 2.89.

Closed Soilless Systems Closed systems use the same nutrient water and circulate it relatively long. In these systems, the nutrients in the solution are cycled to reuse again, and the solution's concentration of nutrients are checked and regulated likewise. Balancing and regulating the nutrient solution is a challenge in a closed soilless system. The examination and analysis of the nutrients within the solution is a requirement per week (Elkazzaz 2017). This nutrition solution is going to be recycled regularly. Water and nutrients are constantly monitored. The disadvantage of this technology is that it is electricity-dependent (Lee and Lee 2015).

Open Soilless Systems Open systems use a new nutrient solution for every irrigation period. In these systems, a recent nutrient solution is prepared via adjusting the ingredients in the watering system for every watering cycle. In these systems, there should be a goal specified to regulate the solution that is reaching the roots (Elkazzaz 2017).

On the other hand, the main benefits of this system are that there will be no risk of infection in the plant system as a result of the regular changes in the environment (Jones 2016). Vertical and smart farming can be used with soilless farming techniques. Firstly, vertical farming is one of the suitable configuration options when working with hydroponic systems. Vertical farming is the method of producing crops via a configuration that is multiple layered and controllable with being inside of the buildings where every aspect affecting the improvement of the plant-like saturation of carbon dioxide, amount of illumination, levels of heat and nutrition are under close control to get yields with great qualities and quantities for the entire year without being related on the sun for illumination and different outside obstacles ("Vertical Farming" 2020). Vertical farming could be a considerable solution for indoors and small spaces. Secondly, smart farming is the application of stand-by technology to agricultural production practices to reduce waste and increase productivity. Smart farms, as a result, draw on technical resources to assist in several steps in the production path with planting and soil management, irrigation, controlling the pesticides, monitoring the delivery and so on (Bhagat 2019). On the other hand, smart farming is based on a certain and resource-efficient technique that aims to increase production of agricultural goods efficiency while also improving quality on a long-term basis (Balafoutis 2017). Moreover, using IoT technologies provide solutions to increase productivity on yields. With the wireless sensors, data can be collected from sensing devices and delivered to the main servers

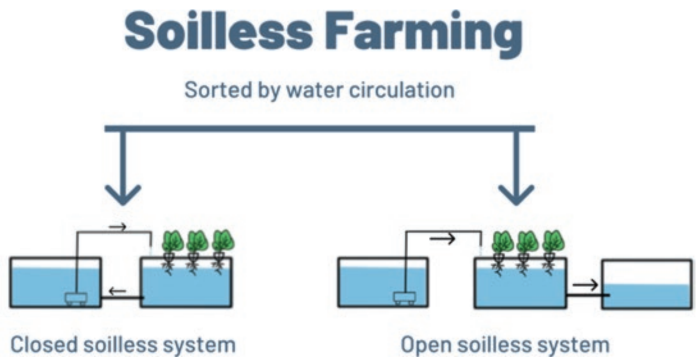


Fig. 2.89 Open and closed methods of soilless farming

using networks. By analysing these data, the most suitable growing conditions can be selected (Ojha et al. 2015).

Fertile lands are rapidly disappearing due to climate change and intensive farming. On the other hand, the world needs to feed more people. Hydroponics, also known as soilless farming, has the potential to convert agriculture by offering a more sustainable and effective alternative to conventional agriculture (van Os et al. 2021). The hydroponic systems have positive attributes, making the method more efficient than traditional farming. The positive attributes of farming without using soil are saving and using more qualified soil for growing the core crops, recovering at least 90% overrun water, working with a stabilised expense of converted water, and the achieved harvest is the most effective when compared to farming with soil (Elkazzaz 2017). There are several advantages of soilless farming. It can be sorted as (Tajudeen and Oyeniyi 2018):

- *Increased productivity*: It has been observed that the products grown with soilless agriculture are more efficient because they spend energy on leaf and fruit development instead of root system development.
- *Lower labour costs and no need for expensive machinery:* Less labour is needed in the soilless farming method because there is no need for ploughing or weeding. On the other hand, there is no need for expensive vehicles such as bulldozers.
- *Is not restricted by the seasons*: With this method, plants are constantly fed with the nutrients and water they need during their growth process. Therefore, they are not affected by the season in this process.
- *Low-cost management*: The cost of running the systems is low, especially for the NFT system, because it is virtually automated.
- *No weed competing:* There is no weed problem in soilless agriculture as no soil is used, and all microbes are carefully selected.
- *There are no pests or diseases in the soil*: Soilless farming has been observed that soilless agriculture has very few pests and disease problems than conventional agriculture.
- *Sensibility for nutrient supply*: Nutrients are either released according to plant requirements or, in most cases, recycled. Therefore, no excessive fertiliser is used.
- *Pollution and preservation of water and land*: Less water and land is used up in soilless farming. Because there is no indiscriminate use of water for irrigation, there is no demand for traditional spacing regulations.
- *Sustentation life in space*: This method has been tested for use on other planets where there is no soil to grow on.
- *More suitable for research purposes*: With this method, it can be used to determine the amount of fertiliser, water or light a plant needs to grow and develop.
- *Greenhouse and vertical farming adaptability:* Soilless farming is commonly practised in greenhouses and is often grown vertically.

Soilless farming is a relatively new technique that has evolved significantly in the 70 years since its birth. Its multiple technologies can be used in both emerging and high-tech space stations. Progression in related technologies such as artificial lighting and agricultural plastics will increase crop yields and decrease production unit costs, so new cultivars with improved pest and disease resistance. On the other hand, governments are determined that there are politically desirable effects of hydroponics. Another desirable effect is job creation. This type of employment generates tax revenue as well as personal income and improves the quality of life ("Future" 2021). There are several things for governments to do for the success of the soilless farming process. The government should consider it as a vital part of the nation's food production chain. The government must provide credits to encourage entrepreneurs and young generations to invest (Tajudeen and Oyeniyi 2018). However, there is a dearth of technical knowledge of this new technique among farmers and horticulturists in many nations, and well-trained employees are required. Significant progress has been achieved recently in the development of economically proper soilless systems, and there is now a broad range of business applications in countries that have implemented farming technologies (Elkazzaz 2017). Accordingly, this deficiency can be eliminated by providing innovations in the field of education. More people can be employed in the future. Although methods that increase productivity, such as vertical farming and smart farming, continue to increase, some plants will depend on the soil to grow. With all technological advances, soilless farming is free of all of the current issues that soil has, making it a proper alternative to soil farming to reach a world without hunger by the year 2030 (Tajudeen and Oyeniyi 2018).

2.33 Spatial Computing

In 2003, Simon Greenwold, who was a researcher in MIT Media Lab, defined spatial computing as follows: human interaction with a machine in which the machine keeps and manipulates referents to real objects and environments (Greenwold 2003). We can explore the concept in detail in three main parts, which are virtual reality (VR), augmented reality (AR) and extended reality (XR).

A. *VR (virtual reality)* is a cutting-edge human-computer interface that creates a lifelike world. It replicates a person's physical presence in both the real and virtual worlds (Zheng et al. 1998). It is a fully immersive, engrossing, interactive alternate reality experience in which the participant is completely engaged in sophisticated human-computer interface technology (Halarnkar et al. 2012). The virtual world allows the participants to move freely (Zheng et al. 1998). They may look at it from a variety of angles, reach into it, grab it and change it. They can engage with the virtual world via traditional input devices like a keyboard and mouse or multimodal equipment like a wired glove, omnidirectional treadmill and/or a Polhemus boom arm (Halarnkar et al. 2012). There is no little screen with symbols to manipulate nor are there any commands to input to make the computer do something (Zheng et al. 1998).

Based on the definitions above, it is reasonable to conclude that certain factors define the quality of any VR system. The three (3) characteristics referred to as the 3 "I" or triangle will be the subject of this review. Immersion, interaction and imagination, or presence, refer to the feeling of being involved in or a part of a computer-generated environment. This is due to the system's stimulation of the human senses (haptic, aural, visual, smell etc.). Interaction is a way of talking to the system, although unlike traditional human-computer interaction (HCI), which employs 1–2 dimensional (1D, 2D) means such as a keyboard, mouse or the keypad, VR interaction is commonly done using three dimensional (3D) means such as a head-mounted device (HMD) or a space ball. VR interaction systems have some characteristics, including effectiveness, real-time responsiveness and human engagement. The system designer's imagination might be thought of as a strategy for achieving a certain goal. VR systems are used broadly for solving complicated problems in a variety of sectors. Their effectiveness as a more efficient way of communicating concepts than traditional 2D drawings or text explanations cannot be denied (Bamodu and Ye 2013). Virtual reality is divided into three levels:

(i) *Non-immersive*

This level is typically encountered on a desktop computer, where the virtual environment is created without the need for any certain hardware or processes. It has the potential to be used for training reasons. Almost any event may be reproduced if the necessary technology is present, which eliminates any potential threats. Pilots can use flight simulators to experience and prepare for circumstances that are either impossible or too dangerous and expensive to replicate in real-world training. The illusion of immersion is created by the user's ability to interact with responsive computer-generated characters and behaviours (Halarnkar et al. 2012).

(ii) *Sensory-immersive (semi-immersive)*

In this method, real-world modelling is crucial in a variety of virtual reality applications, including robot navigation, building modelling and flight simulation. The user can navigate a visual depiction of himself within the virtual world. As an example, the CAVE is a 10'x10'x9' cube in which the user is surrounded by projected pictures, giving the impression of being completely immersed in the virtual environment (Halarnkar et al. 2012).

(iii) *Neural-direct (fully immersive)*

The most significant concept in virtual reality, as well as the ultimate aim, is neural-direct. Immersion into a world in which the human brain is directly linked to a database as well as the viewer's present position and orientation is the goal of this sort of virtual reality. It fully ignores the equipment and physical senses in favour of immediately transferring a sensory input (Halarnkar et al. 2012).

B. *Augmented reality (AR)* is defined as a real-time, indirect or direct view of a physical, real-world environment that has been enhanced by the addition of virtual computer-generated information (Carmigniani et al. 2011). Augmented reality (AR) is a broad term that encompasses a variety of technologies that display computer-generated content such as text, pictures and video onto users' perceptions of the actual environment. Academics first described AR in terms of particular enabling equipment, such as head-mounted displays (HMDs). However, claiming that such definitions were too basic for a changing and increasing industry, three criteria may be used to define AR experience: (a) a combination of real-world and virtual components, (b) that are interactive in real-time and (c) that are registered in three dimensions (3D) (Yuen et al. 2011). There are many different types of augmented reality, but they all share a few things in common: screens, graphical interfaces, trackers and processors. There has to be a way for users to comprehend both real situations and the digital format provided information, a pointing instrument (e.g. a mobile device), a way to guarantee that the digital information is properly coordinated with what the consumer is currently seeing in real-time, and software program to handle the display. Creating applications determines how these elements are assembled and then used (Berryman 2012).

The possibilities for spatial computing technology are endless: simulation of surgical procedures, archaeology with site reconstructions, virtual museum tours, architecture, phobia treatment, training with simulators and many sorts of learning. The importance of virtual reality in education and learning derives from its potential to improve and support learning, boost memory capacity and make better judgments while working in a fun and engaging setting. When we read textual material (such as a printed document), our brain participates in an interpretation process, which increases our cognitive efforts. Understanding gets clearer while utilising virtual reality since there are fewer symbols to comprehend. For example, picturing the process rather than reading a verbal description makes it simpler to understand how a machine performs. With further VR technology, it becomes much easier to visualise. Virtual reality-based learning has been shown to improve both test performance and boost learners' level of attention by 100% (Elmqaddem 2019). Virtual reality (VR) is a cutting-edge teaching method for medical professionals. It can be utilised to provide adequate medical communication for a variety of conditions. It is often used to identify and investigate bone structure in orthopaedics. Medical students are now able to perform surgery virtually by step-by-step learning. Furthermore, VR is beneficial in the treatment of cancer patients. The patient's chemotherapy is carried out easily with high precision. By using a VR headset, one may view the patient's body and parts from various angles. On the patient's side, when they wear VR glasses, this technology boosts their confidence by reducing their apprehension since it gives more realistic information. This technique allows a cardiac surgeon to monitor a patient's heartbeat and changes in rhythm (Javaid and Haleem 2020). AR may be utilised to present a real-world battlefield environment and augment it with annotation data for military applications. Liteye, a firm, studied and developed certain HMDs for military use. A hybrid optical and inertial tracker with tiny MEMS (micro-electro-mechanical systems) sensors was created for cockpit helmet tracking. The use of AR for military training planning in urban terrain is effective. Arcane, a company, created an AR approach for displaying an animated terrain that may be utilised for military intervention planning. The National Research Council of Canada's Institute for Aerospace Research (NRC-IAR) developed the helicopter night vision system using AR technology to extend the effective range of helicopters and improve pilots' capability to control inclement weather. Practising in massive battle situations and replicating real-time enemy action, as in the battlefield augmented reality system (BARS), may provide additional benefits particular to military users. The BARS system also includes tools for authoring new 3D information into the environment, which other system users may see (Mekni and Lemieux 2014). Application areas of spatial computing can be seen in Fig. 2.90.

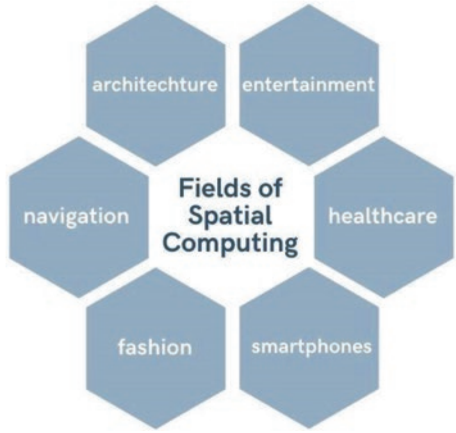


Fig. 2.90 Application areas of spatial computing

Fixed exterior systems, mobile interior systems, mobile exterior systems and mobile interior and exterior systems are the five types of systems of augmented reality. A mobile system can be defined as a system that allows the user to move around without being restricted to a single room, and therefore allows users to move using a wireless connection. Static systems cannot be relocated, and users must utilise them anywhere they are established, with any ability to move unless they are moving the entire system configuration. The sort of system to be developed is the first decision that programmers must consider since it will guide them in selecting the tracking system, display option and potentially interface to employ. For example, installed systems will not employ GPS tracking, but exterior mobility systems will (Carmigniani et al. 2011). Extending reality, which might be called the future technology platform, has altered the way we work, learn, engage and amuse by integrating the physical and digital worlds. It also affects how companies train their staff, service their customers, generate things and manage their value chain.

C. *Extended reality (XR)* stands for augmented reality (AR), virtual reality (VR) and mixed reality (MR) (MR). AR merges physical and

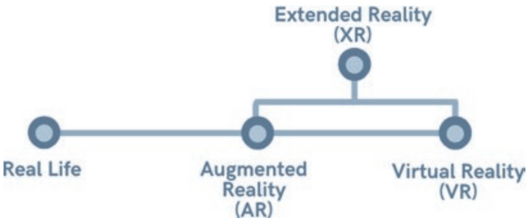


Fig. 2.91 The scope of XR

virtual components in a real-time projection, whereas VR enables users to control and steer their actions in a simulated actual or fictional world (Chuah 2018). Figure 2.91 shows the scope of XR.

The concept "mixed reality" was used to characterise a range of virtual and augmented reality (VR/AR) technologies that combine the real and digital worlds. MR is a concept that is occasionally defined variably, and based on its meaning, it might include or exclude specific VR or AR implementations. As a result, the concept of "extended reality" has lately gained popularity as a catch-all word for AR, VR and MR. The terms VR and AR are used to refer to gadgets that fully block the user's sight of the actual world and XR to relate to devices that allow users to see both the real and digital worlds. In Table 2.5, the characteristics of several XR device types are listed (Andrews et al. 2019).

VR, unlike AR, obscures the actual world and digitally places items (such as music, movies, images and messages) throughout the real world in a completely manufactured manner. Users may mentally immerse themselves in the simulated 3D environment and experience the sense of "being physically there", thanks to VR's capacity to mimic detailed real-life scenarios. As a result, virtual reality (VR) has been dubbed integrated virtual multimedia that produces a 3D, virtual imagined and interactive entertainment environment that a person perceives as being in the actual world (Chuah 2018). Whereas virtual reality innovation, or virtual environment as Milgram refers to it, totally immerses consumers in an artificial world without allowing them to see the reality. Augmented reality (AR) technology enhances the perception of reality by overlaying digital environments and cues onto the physical world in real-time (Carmigniani et al. 2011). The goal of AR is to make the person's life easier by introducing virtual knowledge not just to his surrounding environment but also to any indirect view of the physical environment, such as a video broadcast. The person's perspective of and connection with the physical environment is improved through augmented reality (Carmigniani et al. 2011). As a result, people engage with real-time virtual 3D items seamlessly and intuitively, seeing them as realistic and learning to comprehend, analyse and connect with the items (Halarnkar et al. 2012).

VR is a technology that draws inspiration from a wide range of areas. However, it is distinguished by a close relationship between human aspects and assisting technology as a discipline. Hardware, programming, human aspects and transmitting VR via the Internet are the most pressing issues (Zheng et al. 1998). Today, AR is everywhere in our daily life. The wide usage of AR has become feasible due to the low cost of smartphones and other technology designed to process and present data at high rates. In addition, experts anticipate that the advancement of portable devices that can deliver augmented reality content and experiences will keep accelerating. As the technologies that enable AR to continue to improve, research and development on how AR may be used in education will keep on improving simultaneously (Yuen et al. 2011). In the upcoming years, spatial computing offers a wide range of ground-breaking abilities; for instance, instead of focusing on the shortest path or the travel time, companies have come up with eco-routing, which involves determining paths that reduce greenhouse gas emissions. UPS saves over 3 million gallons of gasoline each year by using smart sequencing, which avoids left turns. When customers and owners offer eco-routing options, such savings can be increased substantially (Shekhar et al. 2015).

Table 2.5 Characteristics of several XR device types

Extended reality classification	Hardware examples	User interface	Technical strengths	Technical limitations
Virtual reality	• Oculus rift	• Handheld motion-tracked controllers	• Superior 3D graphics performance and highest resolution	• User has no direct view of physical environment
	• HTC vive			• Requires controller inputs
2D augmented reality (indirect)	• iPhone	• Touchscreen	• Widely available, inexpensive	• Phone or tablet must be held or mounted
	• iPad			• Requires touch input
	• Android devices			
2D augmented reality (direct)	• Google glass	• Side-mounted touchpad	• Lightweight head-mounted display	• 2D display
		• Voice		• UI does not interact with physical environment
3D augmented reality	• Microsoft HoloLens	• Voice	• Touch-free input	• Narrow field of view for 3D graphics
	• Magic leap	• Gaze	•3D display	
	• RealView Holoscope	• Gestures	• Full visibility of surroundings	

2.34 Wireless Power Transfer

Wireless power transfer (WPT) is currently one of the trendiest subjects in research, and it is getting a lot of attention. WPT has already made great progress in the field of charging mobile devices or charging electric vehicles, and in the future decades, the WPT sector is anticipated to develop steadily (Rim 2018). WPT is the transferal of electrical energy without the need for cables based on electric, magnetic or electromagnetic fields that change over time (Georgios and Evangelos 2019). The notion of WPT is based on Faraday's law of induction, which is well-known among engineers. According to this rule, alternating current (AC) generations are caused by the changing magnetic field (Würth Elektronik 2021). There have been a lot of fascinating initiatives in the history of WPT. Even though the inherent complexity of this technology prevented it from being commercialised, the improvements deserve consideration and are worth investigating. The infographic timeline in Fig. 2.92 summarises the history of WPT (IEEE 2021).

WPT is divided into two categories depending on the length of transmitter-to-antenna distance. The term "near-field WPT" refers to when the antenna is located close to the transmitter. On the other hand, if the transmitter and the antenna are further or far apart, this is referred to as "far-field WPT".

An inductive and a capacitive, also known as primary and secondary respectively, coils are used in close distance technology. These coils have been known as Tesla coils since Nikola Tesla invented them in the early 1890s. They can be used to transfer power between themselves by employing the transformer principle. That is electromagnetic induction, electric power through spark-excited ratio frequency resonant frequency. The alteration of the magnetic field and the passage of a current that oscillates through the primary coil conducts the secondary coil. The primary coil carries a magnetic flux around it, produced by the oscillating current it possesses. Because these coils are looped around the secondary coil, a voltage is induced in the secondary coil. The largest distance that may be covered by this way of delivering electricity via electromagnetic induction is 5 cm. This is since,

Fig. 2.92 A brief story of wireless power transfer. (IEEE 2021)

as the distance between primary and secondary coils increase, the loss of magnetic flux exponentially increases, resulting in a significant power loss.

Long-distance technologies, sometimes known as radioactive technologies, are utilised to achieve long-range wireless uses with distances of several kilometres range. Microwaves and lasers are the most common technologies for long-range communication. The wavelength steers the transmitter in the receiver's direction, while diffraction limit is employed in radio frequency design, allowing this application to be free of electromagnetic radiation dangers and achieve nearly fully efficient transmission. Several methods of WPT technology are shown in Fig. 2.93 (Lokesh 2020).

There are several uses for WPT. To begin with, it has the potential to replace existing charging methods. Instead of using a power cord to charge a phone or laptop, wireless power may be applied in the house, allowing computers or smartphones to charge constantly and wirelessly. Another application of WPT is the charging of electric vehicles (EVs). Chargers for EVs are among the higher-level uses. As EVs grow increasingly common on the road, fixed and even mobile WPT devices can improve the viability of driving one (Mehrotra 2014). Implantable medical devices are also among the usage areas of WPT. These devices have a very low power demand and thus can be powered by WPT to substantially increase the operation time in vivo (a medical procedure that is done on a living organism), improve the

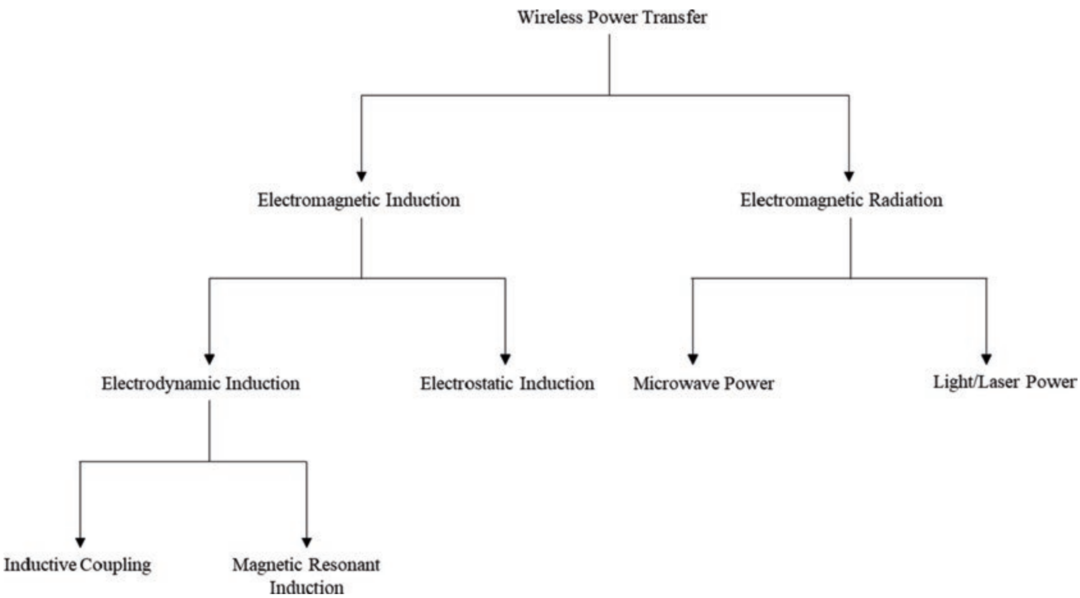


Fig. 2.93 Schematic of different methods of WPT. (Lokesh 2020)

accuracy of diagnosis and therapy, minimise the rate of misdiagnosis and achieve permanent operation in vivo, all while improving patient comfort. WPT can also be used in industrial environments where it is impossible to use wire for power transmission, such as underwater and chemical areas (Wang 2018).

Even though the notion of wireless power transmission has been around for over a century, it is regaining popularity in the twenty-first century as a result of the widespread use of smartphones and other mobile devices (Allied Components International 2019). The widespread use of WPT has the potential to bring many benefits. Such as the ability to decrease or eliminate the usage of wires and batteries. Therefore, reducing the use of copper- and aluminium-based electric cable (Sumi et al. 2018). In addition, thanks to WPT, the use of elements used in battery technology is reduced. Until recently, charging difficulties have made EVs less appealing to consumers, despite several government incentive programs. However, charging becomes the simplest process by wirelessly transmitting energy to the EV. Furthermore, projections indicate that the battery capacity of EVs equipped with WPT could be reduced to 20% or less compared to those without WPTs (Li and Mi 2015).

WPT eliminates the need for power ports, which solves significant problems of conventional charging methods such as mating cycles, deterioration of connection points, thus greatly contributing to device longevity. Additionally, removing power docks and ports allows manufacturers to design completely sealed devices, advancing water-resistant to waterproof, thus increasing durability and longevity (Würth Elektronik 2021). WPT offers more efficient charging systems making it a must-have feature for IoT-enabled portable devices like cell phones, digital cameras and camcorders, laptops and tablets, wearable electronics and more (Patil et al. 2020). WPT technology has many advantages and disadvantages. Table 2.6 shows the detailed advantages and disadvantages of WPT (Bhardwaj and Ahlawat 2018).

Projections state that it will be possible to utilise electric equipment without the need for a wire in the future. The following section is a discussion of potential applications of wireless power transfer technology, summarised by Sumi et al. (2018).

Table 2.6 Advantages and disadvantages of WPT technology

Advantages	Disadvantages
Eliminates possible power transmission problems caused by short circuits in wired connections	Execution of WPT systems has significant capital costs
Reduces power losses attributable to wired connections	Less effective in comparison to customary charging
Enables and eases the global interconnectivity of power plants	The use of WPT might result in obstructions in correspondence frameworks

Bhardwaj and Ahlawat (2018) and Shanmuganantham et al. (2010)

(a) Solar Power Satellite

Satellites equipped with solar panels can be used to gather as much solar energy from the sun as possible in orbit. A microwave transmission device is used in satellites to convert electricity into microwaves for transmission to a microwave receiving antenna back on Earth. These microwaves transmitted from space can be converted into energy to power homes, workplaces and so on. Despite being in the early development stages, the use of WPT through satellites is a highly promising source of clean and renewable energy (Cuthbertson 2021).

(b) Home Appliances That Are Powered Wirelessly

The future developments of WPT are likely to produce a power transmission device within the home that will send electricity to the entirety of home appliances, including televisions, laptops, lamps, irons, sound boxes, fridges and mobile phones. The proposed transmitting device would send out electricity. Each appliance featuring WPT receivers could use it to power themselves.

(c) Wireless Charging for Electric Vehicles on Way

EVs are projected to be solely powered wirelessly in the future, which would make it possible to charge EVs while driving thus, eliminating the need to stop and charge. Power beam transmitters can be linked to roads and heavy traffic zones with power sources. These transmitters could transform electricity into power beams and project them onto EVs equipped with appropriate receivers to re-convert the power beam into electrical power, charging the car's battery in return.

(d) Wireless Charging Train

In the future, all trains may be powered wirelessly, which would eliminate the need to use wire to link the train. Sumi et al. (2018) propose a wirelessly powered future train model, according to this which a dual-mode power receiver and transmitter would be connected to train poles. All train stations would feature pole(s) equipped with a dual-mode transmitter and receiver. The power would come directly from the power station, to be collected and transmitted by dual-mode transmitters. When utilising a dual-mode transmitter, power reception and broadcast occur at the same time. Power would reach the train through reception made possible by receivers installed on their roofs. There would be no need to utilise wire in this model.

(e) Supplying Homes with Power from the Power Station Wirelessly

Renewable energy sources may be used to generate clean and green power in the future. The generated power from these power stations can be directly and wirelessly transmitted to residential areas. This would be possible through the use of antennas that convert electric power into microwaves and transmit them to another set of antennas that could receive and again transmit power. The final destination would be housing; however, to utilise the power transformed into microwaves, they would require an antenna that could re-transform microwave energy into electrical power.

(f) Controlling a Drone Wirelessly to Extinguish a Fire

Projections state that drones could prove highly useful in emergencies, especially fires. They can be used to carry water pipes and place them in precise locations via a remote-control system. It is thought that fire trucks would carry a transmitter to send power, to be received by an appropriately equipped drone. Drones are invaluable because they can fly where people can't go and take pictures and videos of the situation. Since it will not be possible to connect the drone with a wire in an emergency, it is foreseen that this process will be very useful.

(g) Medical Equipment Can Benefit from Wireless Power

The wireless power supply may be used for medical equipment in the future. A transmitter that is directly linked to the power station may be used to establish a viable power supply. This would transmit the power to a receiver installed in the hospital to create wireless electricity to power medical equipment.

Regarding economics, it is forecast that the WPT market will reach a size of 11.3 billion USD by 2022 and 35.2 billion USD by 2030, which is a substantial increase from 2.5 billion in 2016. This growth is expected to be mainly driven by advancements in far-field transmission, the need for effective charging systems that WPT can offer and increased needs for appliances powered by batteries (Markets and Markets 2017; Wankhede et al. 2021). An additional driving factor is presumed to be IoT-enabled devices, such as cell phones, digital cameras and camcorders, laptops and tablets, wearable electronics and home electronics, gaining more and more traction, and their WPT featuring design needs (Patil et al. 2020). If not addressed, the initial capital costs of installing WPT systems are expected to have detrimental effects on the growth of its market (Markets and Markets 2017).

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