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Emerging Technologies of the Fourth Industrial Revolution

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Since the first industrial revolution, technological advances and innovations have always emerged to drive progress in every aspect of society. For example, with the discovery of electricity and the creation of the assembly line in the second industrial revolution, mass production was made possible to supply large quantities of goods to consumers. In addition, many technological breakthroughs—including the use of mainframes, the internet and information and communication technologies—have shaped the course of digital era and reinforced globalization since the 1960s. Similarly, as the fourth industrial revolution or Industry 4.0 is underway, both new and existing technologies also come into existence and continue to develop to reach their full potentials. To better understand the form and nature of those technologies, Klaus Schwab, who introduced the term 'fourth industrial revolution' has categorized those technologies under physical, digital, and biological dimensions (Schwab, 2016). However, it is hard to cover all the technologies in one paper due to their breadth and complexity. Therefore, the aim of this aide-mémoire is to selectively introduce the emerging technologies, which are substantially progressing under the fourth industrial revolution, and briefly explain the significance of them in general.

❖ Smart Factories

Imagine that, in a factory, machines could manage the entire production process with minimal human intervention. When raw materials and production inputs almost run out of stock, a system is capable of estimating and making the right amount of order for robots to fill in the shortages of materials for the next production. Furthermore, the production levels can also be easily determined based on data of production outputs and product demand, which are shared between factories and supply chains. These are some examples of an automated and smart process in a smart factory, which is one of iconic features of Industry 4.0.

In general, a smart factory is defined as "a flexible system that can self-optimize performance across a broader network, self-adapt to and learn from new conditions in real or near-real time, and autonomously run entire production processes" (Burke, Mussomeli, Laaper, Hartigan & Sinderman, 2017, p. 5). In fact, most of the emerging technologies, such as Artificial Intelligence (AI), Big Data Analytics, Autonomous Vehicles (AVs), 3D Printing and Virtual Reality (VR) are incorporated in every aspect of smart factories. But the foundation of a smart factory is cyber-physical system enabled by the Industrial Internet of Things (IIoTs) which plays a significant role in transferring, storing and analyzing information and data from various parts of production process and the assembly line. In addition, digital interconnections in a smart factory, which are established to link various parts of the whole manufacturing process, are made possible by the combined operations among sensors, data and analytics (Bansal, 2019).

There are at least several ways that a smart factory impacts the manufacturing industry. Since the cyber-physical system in a smart factory is highly connected and optimized, it will maximize the productivity and efficiency of the entire process (Burke et al., 2017). For instance, according to GE Healthcare, productivity in floor space had increased by 66 percent after a complete transformation into a

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smart factory (OTTO Motors, 2019). Moreover, the flow of information is easily transferred and analyzed, as sensors and chips are embedded within devices, machines and tools. As a result, greater collaborations among departments, suppliers and customers are significantly achieved. Also, it enables predictive maintenance ability, which serves as a system that is able to learn to evaluate conditions of machinery and alert technical teams to prepare the necessary checkups and repair in advance or whenever needed. Therefore, the possibility of unexpected downtimes in shop floors and the assemble line is minimized (WEG, 2019).

Smart Factory

Source: Envato Elements

❖ Robotics

Another branch of the current digital revolution is the development of robots. Notably, the most recognized feature of Industry 4.0 is the deployment of robots in smart factories. Basically, robotics is an interdisciplinary study of science which is involved with engineering, mathematics, computer science to create robots; and the sole purpose of robots is to perform works and services in place of human, as well as executing tasks which are not safe for human to complete such as exploring outer space and the depth of oceans (Built In, n.d.). Generally, robots possess three main characteristics as follows:

1. Certain mechanical designs are built for robots to enable them to adapt to specific environments and settings.

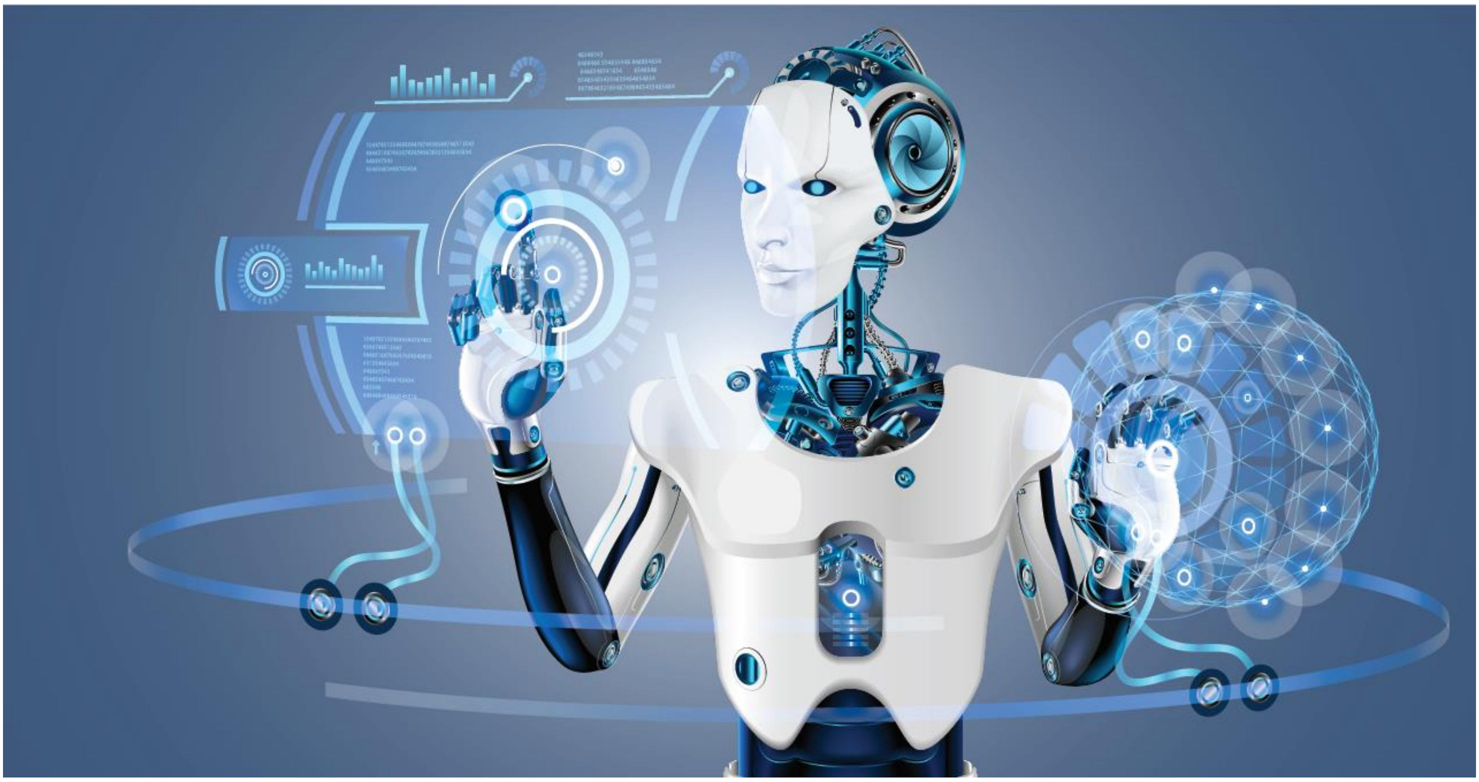
2. Electrical sources, such as electric and solar batteries, are required to power and support their functions.

3. Computer programing and coding is essential for defining functions and purposes of robots (Built In, n.d.).

There is a wide range of areas and industries that robots can be used to either replace human labor or assist workers. Additionally, there are different types of robots employed by human to serve different purposes. Particularly, while collaborative robots (Cobots) work in close proximity to human to provide assistive capabilities such as lifting and assembling light materials, industrial robots work in isolation from workers like handling heavy manufacturing, which is often dangerous and requires more strength (Roehl, 2017). Nevertheless, robots cannot perform all types of tasks in industries since there are some parts human is in a more convenient position to handle the tasks very much better than the robots. To illustrate, even though robotic arms are used to install seats of the Model 3—an electric car of Telsa—workers are proved to be more efficient and consistent when they tightened the bolts that transfer power to the seats (Boudette, 2018).

As robots are becoming more advanced and widely adopted to work alongside human, its impact on the society, especially on employment, could be double-edged. Conspicuously, some repetitive jobs have been replaced by automation and robots to yield higher efficiency and productivity. For instance, Amazon has replaced workers with robots to handle warehouse tasks such as packaging and moving products, allowing the company to outpace its competitors in terms of product packaging (Computer Hope, 2020). Additionally, it was predicted that around 20 million manufacturing jobs will be replaced by automation and robots by 2030 (Cellan-Jones, 2019). At the same time, the demand for new, complex jobs that require high digital skills will also rise, which in some parts substantially could shape the future of the workforces. According to McKinsey, job growth in new fields, such as blockchain and Artificial Intelligence, would counterbalance jobs losses, and it is estimated that approximately 555 to 890 million new jobs that require human to work alongside machines and technologies will emerge by 2030 (Wong, 2019). Thus, it is crucial that the current workforce should prepare for new skills and adapt to the digital transformation.

Robotics for Manufacturing



Source: The Manufacturer

❖ 3D Printing

3D printing technology is not really a new concept. The idea was first discovered by Hideo Kodama in 1981 and materialized later by Charles Hull in 1984 although it was still in early stage of development (Goldberg, 2018). It is until recently that the technology has become advanced and widely practiced. Also known as additive manufacturing, 3D printing technology is a process of creating a three-dimensional object using 3D printers (Lacoma, 2018). By adding each layer successively, a 3D printer transforms a digital 3D model into a solid object, which could be any types of products, materials, and equipment. Particularly, as the 3D printing is becoming advanced and cost-effective, 3D printing is used to produce end-use production parts, such as aerospace components, automobile parts and medical products (Hornick, 2016). In addition to the use of plastic for creating objects, there are different printing techniques and 3D printers that use a variety of materials. For instance, by using a technique called 'Direct Metal Laser Sintering' (DMLS), industrial product parts and prototypes can be created from metals, including aluminum, copper and steel (Yoders, 2018).

3D printing technology provides the manufacturing industry with a considerable advantage, especially in reducing production cost. Evidently, in 2016, 3D printing saved Volkswagen at least USD160,000 in one manufacturing site as the company adopted the technology to create tools and jigs, which are used at the assembly line (Gewirtz, 2019). Apart from the usage in the manufacturing industry, 3D printing is also incorporated into the healthcare sector. Specifically, human organs such as heart and kidney implants could be replicated by 3D printing at low cost (Boissonneault, 2018). In addition, 3D printing technology can aid product design and development. Particularly, 3D printing technology allows a variety of industries and fields, such as engineering, interior design and footwear to embark on rapid prototyping process, which involves testing and developing design ideas into prototypes or models in a shorter time (AMFG, 2018).

3D Printing of Heart

Source: Pegus Digital

❖ Autonomous Vehicles (AVs)

The development of Autonomous Vehicles (AVs) or self-driving cars forms another part of the physical dimension of Industry 4.0 technologies, which has gained a progressive pace in the automobile industry. Simply put it this way, an autonomous or automated vehicle refers to a vehicle that automatically operates without human control (Synopsys, n.d.). AVs, nevertheless, vary according to their levels of automation since some of them still require a certain level of engagement from drivers. Hence, to specify the state of the AVs, the National Highway of Traffic Safety Administration (NHTSA) in the U.S. develops five levels of automation, ranging from a non-autonomous operation to fully functional automation. The automation levels are determined as follows:

- Level 0 (Zero Automation): Main vehicle operations, including steering, braking, accelerating and safety control are entirely performed by drivers.

- Level 1 (Function-specific Automation): Drivers are responsible for managing safety control during the whole trip, but there are some function controls to assist the drivers. Those functions—including adaptive cruise control and steering—work separately and could automatically receive limited authority to perform in emergencies.

- Level 2 (Combined Function Automation): Two or more functional controls cooperate to perform primary operations, and drivers can disengage from physical controls, such as steering and accelerating. Still, drivers must be attentive to take control of vehicles quickly and monitor the roadway for the whole time.

- Level 3 (Limited Self-Driving Automation): Self-driving cars receive full autonomy to perform primary functions and safety controls, and automatically monitor the roadway most of the time. When the system detects certain conditions, such as entering construction areas, the driver will be alerted in advance so that he could have enough time before resuming control of the vehicle.

- Level 4 (Full Self-Driving Automation): When given destination or navigation input, the vehicle assumes overall driving operations and no longer requires control from drivers. – (U.S. Department of Transportation, 2013)

Autonomous Vehicles

Source: CIO

The impact of AVs on transportation system is potentially huge. Even though the technology is still at the early stage of development, it has a great potential to change how we use transportation in various contexts and settings. Particularly, the use of AVs is gaining attention in the industry sector for its part in reducing accidents, improving efficiency in logistics and supply chains, and decreasing negative impacts on the environment (Elementum, 2016). In addition, the low operation costs is the main reason manufacturers consider to employ industrial mobility technologies, such as autonomous trucks and cranes, even though in the meantime less than 10 percent of them have used autonomous mobility due to the cost of investment on the technology (PwC, 2018). With AVs, there will also be a shift in urban transportation system. For example, since public buses struggle to operate within crowded areas and busy roads, autonomous shuttles—which are less expensive—are able to accommodate up to 15 people and travel at a short distance, underscoring an ideal solution for mass public transportation (Apur, 2018).

❖ Virtual Reality and Augmented Reality

Like most of the emerging technologies, Virtual Reality (VR) creates another physical layer of Industry 4.0. In a simple term, VR refers to a digitally created environment that a user can perceive through his senses such as sight, hearing, smell and touch (Bardi, 2019). Often projected by Head-Mounted Displays (HMD) and interacted with by digital sticks, VR allows users to immerse themselves into digital worlds. For instance, a diver could witness an artificial ocean floor, which surrounds himself with realistic organisms and objects, such as whales and coral reefs, without having to be physically going to the ocean.

There is another technology known as Augmented Reality (AR) that falls under the family of immersive reality. Augmented Reality also depicts artificial objects through wearable devices, but this technology works conversely from the virtual reality. While VR creates a whole virtual environment in which a user can immerse, AR supplements real scenes with 3D animations and objects, which are displayed on smart phone's screens and smart glasses (Kenton, 2018). In addition, AR technology is aware of spaces and curves of physical environments through cameras and sensors to adjust digital objects to fit the actual positions within the environments. For example, Pokémon Go adopts the technology into its system to allow gamers to catch interactive animals or Pokémon, which are shown in the game using real views of the gamers' surroundings. There is also another immersive technology called Mixed Reality (MR). which utilizes the concept of augmented and virtual reality to enable users to engage in near-real digital world. Either rendering an artificial or a real environment to create an immersive world, mixed reality allows users to manipulate digital objects, which are visible in a holographic form (Microsoft, 2018).

The most common use of reality technology can be found in the entertainment industry, in which VR has been optimized to give video gamers a new level of experience. As popular as it would seem, the technology also has potentials to impact a variety of fields and industries. For instance, the technology can transform education and learning. With VR, the conventional way of learning will be changed to enable modern learners to grasp their lessons effectively. Teaching is to be assisted with VR, which could serve as a very powerful tool and platform to allow learners to witness real places instead of illustrations in books and in the traditional reading materials provided in class by the instructors (Babich, 2019). For example, supported by the Infocomm Media Development Authority, a statutory board of the government of Singapore under the Ministry of Communications and Information, Singaporean primary schools have opted for Virtual Reality solutions to let their students virtually experience on-site visits at various different places, such as religious temples and agricultural farming fields (Bhunia, 2017).

Virtual Reality

Source: RoboDK Inc.

Immersive reality technologies are also useful in areas, such as engineering, design and construction, which require visual modeling. In particular, to assist technicians in modeling complicated wiring system aircraft engine, Boeing adopted AR using Google glass to create interactive and virtual 3D diagrams so that the technicians could see the inside of aircraft parts (Kantor & Paul, 2018).

Besides, the Virtual Reality technology is also shaping healthcare sector in a significant way, specifically in assisting surgical procedures and medical trainings. Normally, surgical trainees are allowed to perform only in some cases of surgical operations which require less expertise. But with VR technology, trainees can run their own surgical simulations, which are safer and less dependent on trainers (Flink, 2018). In addition, the technology can be used for medical therapy, particularly for treating children with autism. Since autistic kids have difficulty in socializing with people, the technology has the capability to create virtual situations, in which they are able to get to learn and practice communication techniques and social skills (Gottsegen, 2019).

❖ Cloud Computing

While different types of computing technologies—the use of computer systems to communicate information, handle works and solve problems in different environments —are exponentially developed and implemented, the cloud computing is widely adopted across institutions, organizations and businesses. This cloud computing is also considered as one of the digital forms of the Industry 4.0.

Normally, digital documents have been stored in physical storage devices like local and external drives. With cloud computing, however, users are able to digitally store their data and software on the cloud or the internet. Cloud computing technology also serves different services, including cloud-based servers, networks, software applications and databases, which enable users to access their work and applications anywhere as long as their digital devices are synchronized and connected to the internet (Frankenfield, 2019). Cloud computing services are implemented in three different ways:

1. Infrastructure as a Service (IaaS): Companies such as Microsoft Azure and Google Comte Engine act as data centers that involve building and maintaining physical infrastructure necessary for establishing servers and data storage space. They offer their cloud-based services to consumers who want to develop and employ their own operating systems, software and development tools. In other words, the consumers pay for the infrastructure cost so that they do not need to build hardware and software to create their own cloud networks.

2. Platform as a Service (PaaS): Software and application developers can opt for PaaS solutions if they want to focus on developing their products. In addition to infrastructure resources, a PaaS provider offers customers with operating systems, middleware and database management systems. This kind of service helps eliminate a great expense for both hardware assets and development tools, which largely benefit web-based application developers who need to boost their operations.
3. Software as a Service (SaaS): This form of cloud computing is the most common pay-as-you-go service that has complete software solutions to deliver applications for users. For example, Internet-based programs, such as Microsoft Office 365 and G Suite, provide businesses and institutions with plenty of useful office applications, with a high level of data security (Felter, 2020).

One key impact of cloud computing technology is on organizational process and management. It was found in 2016 that most companies in IT-related industries would choose to build their IT infrastructure on private clouds in the next two years (Burger, 2019). In addition, since the cost of purchasing and maintaining local machines or servers to store and process data is high, most organizations have moved to implement cloud computing solutions to reduce the cost, as well as developing their product designs based on constant data collection and analytics as a part of iterative development process (Hardy, 2018). For example, by using multiple cloud computing services, co-located data centers, and automated IT infrastructure, Uber is able to constantly improve and scale up its service in a more efficient manner to respond the increasing need for ride-hailing service (Dignan, 2019).

These new technologies and digital innovations are just a part of the fourth industrial revolution, and there are many others, including quantum computing, gene sequencing and new materials, which are at different levels of development. However, some of the technologies, such as full self-driving cars, AI and blockchain, are not completely developed and utilized, which therefore need years of research and development to mature these technologies in for business and professional usages. Still, governments, policymakers, entrepreneurs and relevant stakeholders will need to prepare for both positive and negative impacts of the advancement of these technologies that the fourth industrial revolution brings into the new era. Also, regulatory measures and legal mechanisms are required to fully ensure rightful and legal uses of those technological advances for the benefits of all.

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