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INDUSTRIAL REVOLUTION (IR) 4.0 INNOVATIONS

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ABSTRACT

The introduction of Industrial Revolution (IR) 4.0 has brought the creation of innovation either in industries or people's daily life. The implementation of IoT, cloud computing, grid computing, big data and other new fields of IT applications has benefited the manufacturing industries, services in government and corporate agencies as well as the whole human life. As the manufacturing sectors focus to increase productivity by utilising the existing technology or assets, it is believed that IR 4.0 is capable to achieve the goals, vision and mission of the organisations. This paper aims to introduce and explain in detail nine (9) elements of IR 4.0. Furthermore, examples of application for each element are further discussed in terms of industrial, government and human being practices. Implementation of IR 4.0 in education is believed to increase the teaching and learning pedagogies effectiveness, especially in the e-learning area. Nevertheless, to ensure that the dreams can come true, the infrastructures and info structures should be established into Industrial Revolution (IR) so that they can be implemented effectively and able to benefit the organisations and people.

Keywords: Industrial Revolution (IR), Internet of Things, Big Data, Augmented Reality, Cloud Computing

Introduction

Advances in technology change the way humans producing things and delivering services to people. The steps of production in the manufacturing sectors are different from the past due to the enhancement and improvisation of the processes. The advancement of technologies has changed the working conditions and lifestyles of people. These changes of technological advancement over the years are called the industrial revolution.

The industrial revolution started with the first revolution in the 18th century. The use of steam power and mechanisation production was popular in the manufacturing industries. The development of steam power for ships and locomotives brought massive changes to the local economy as humans and goods could move great distances in a few hours and days (Desoutter Industrial Tools, 2021). The use of machinery was 8 times better compared to the volume using the labour energy.

The second industrial revolution began in the 19th century whereby the electricity component and the production line were the main concern. For example, Henry Ford took the idea of adopting mass production from the slaughterhouse in Chicago and transforming it into automobile production. Previously, the process of assembling an automobile took place at one station until complete, which took a long time and required a lot of human power. Today, vehicles can be assembled by part on the conveyer belt. Furthermore, they can be completely assembled at the end of the production line, which is significantly faster, low-cost and requires less human power. The third revolution started in the '70s in the 20th century with the implementation of computing technologies such as memory-programmable controls and computers. The technology automates the entire process without human assistance. Robots are the example of technology that perform the tasks that have been programmed without human intervention.

The 4th industrial revolution was characterised by the application of information and communication technologies to industry, which was built with the existence of infrastructures from the 3rd revolution and expanded by a network connection. The networking capabilities led to communication with other applications and encouraged the automation of all processes through system integration. Therefore, the smart factories will create an environment where production systems, components and people communicate via a network and production that is nearly autonomous.

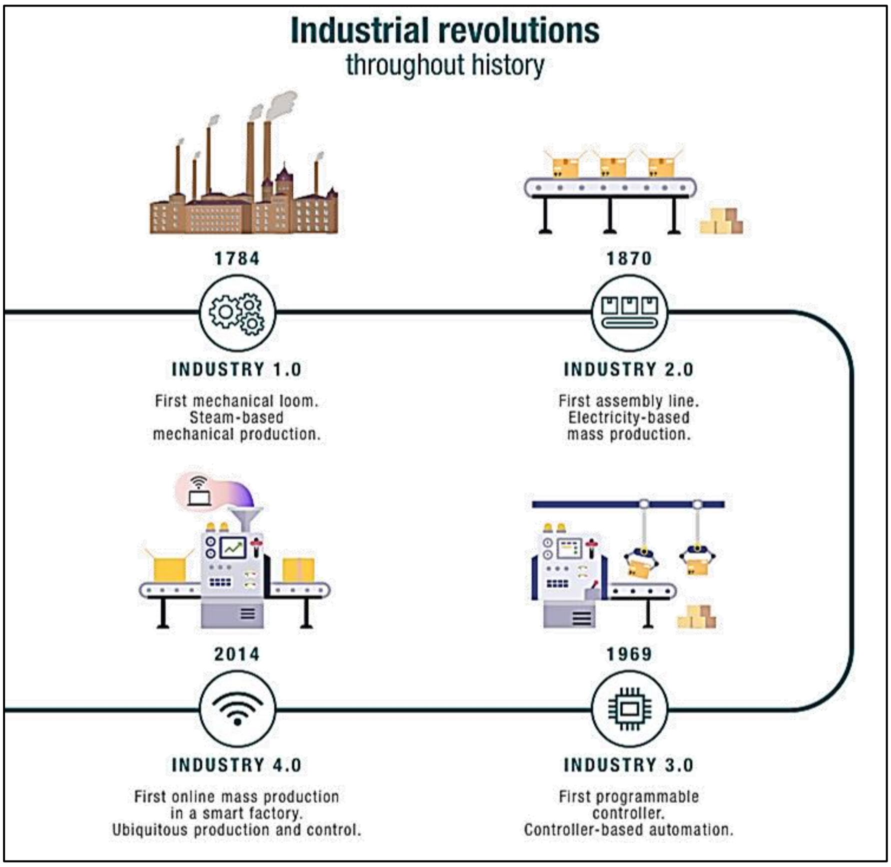

Figure 1: Industrial Revolutions (*Adapted from Iberdrola, https://www.iberdrola.com/innovation/fourth-industrial-revolution*)

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Industrial Revolution (IR) 4.0 Elements

Generally, Industry 4.0 concentrates on the growing trends of process automation and data exchanged within the manufacturing industry. Industrial Revolution (IR 4.0) elements include: (i) Internet of Things (IoT), (ii) Cloud Computing, (iii) Augmented Reality (AR), (iv) Simulation, (v) Robotic Automation, (vi) System Integration, (vii) Additive Manufacturing, (viii) Big Data and (ix) Cybersecurity (Erboz, 2017).

i. *Internet of Things (IoT)*

IoT allows data transfer between objects and humans. It consists of three (3) main relationships in a digital network; between humans and humans, humans with objects and objects with objects. IoT architecture consists of three (3) layers; perceptions, networks and applications (Yang et al., 2011). The perception layer is referring to the peripherals that collect data from the environment such as barcode, camera digital or RFID. The network layer provides a platform for data transmission and the application layer is the interface between the users and IoT devices. The IoT is made based on the development of technologies, real-time analytics, sensors, wireless systems, automation, control systems and machine learning.

IoT platforms are designed to determine the actions based on the pattern of data detected and performed the required action, make recommendations and find the best solution. For example, when you are driving, the dashboard of your car suddenly displays a red signal indicating that the engine is having a problem. Through IoT technology, the sensor from your car will transmit the data to the car manufacturer. The manufacturer will then analyse the car faults and automatically make an appointment with the owner of the car to fix the fault at the nearest car dealer. Furthermore, the IoT ensures that the replacement parts are ready in stock whenever you arrive at the centre (TWI, 2021).

Many smart homes embedded IoT technology to save energy by automatically turning off the devices whenever the device is unused. Lighting, heating, air conditioning, security systems and other smart devices and peripherals are controlled through smartphones or tablets.
Besides, IoT is also applied for healthcare purposes to monitor the sugar level, pulse rate and blood pressure of the patients to avoid serious malfunctions or injuries (TWI, 2021).

Figure 2: Smart home

Figure 3: Propeller sensor in an inhaler to trigger asthmatic attacks

ii. *Cloud Computing*

Cloud computing is on-demand access via the Internet facility, allowing the resources such as application systems, database systems, data storage, development tools, servers, mobiles and networking infrastructures to be used for sharing purposes to reduce capital expenses (Vennam, 2020). Cloud computing helps to lower IT costs by reducing the purchasing, installation and configuration costs as well as managing the resources available at a premise. In addition, cloud computing encourages the use of real-time enterprise applications instead of waiting for a couple of weeks or months for the supplier to install and configure the application at a premise after the purchase.

Generally, cloud computing consists of three common models, namely Infrastructure-as-a-Service (IaaS), Platform-as-a-Service (PaaS) and Software-as-a-Service (SaaS). IaaS enables the end-users to scale and shrink resources such as the servers, networking and storage based on the needed basis, utilisation, optimisation and overbuying the resources. PaaS provides software developers with on-demand platforms such as the hardware, complete stack of software, infrastructures, development tools for development, running, testing and managing the applications without cost, complexity and inflexibility of maintaining the platform at their premise. Meanwhile, SaaS is also known as a hosted cloud application that needs to be accessed via a web browser. The SaaS users must pay the monthly or annual subscription fee. SaaS offers automatic upgrading and protection from data loss.

The type of cloud computing consists of (1) public cloud, (2) private cloud, (3) hybrid cloud and (4) multi-cloud. The public cloud is a cloud in which the service provider might be making the computing resources accessible for free. Amazon Web Services (AWS), Google Cloud and IBM Cloud are examples of public cloud. Private cloud is only dedicated and accessible by only one customer, hosted at on-premises in the customer's data centre, highly secure and customised based on the premise infrastructures. Hybrid cloud combines public and private cloud services. The goal of the hybrid cloud is to establish a mixture of public and private resources for flexibility to choose the most optimal cloud for each application. The multi-cloud is the use of two or more types of clouds for two or more different cloud providers. Almost 85% of organisations have been reported using multi-cloud environments.

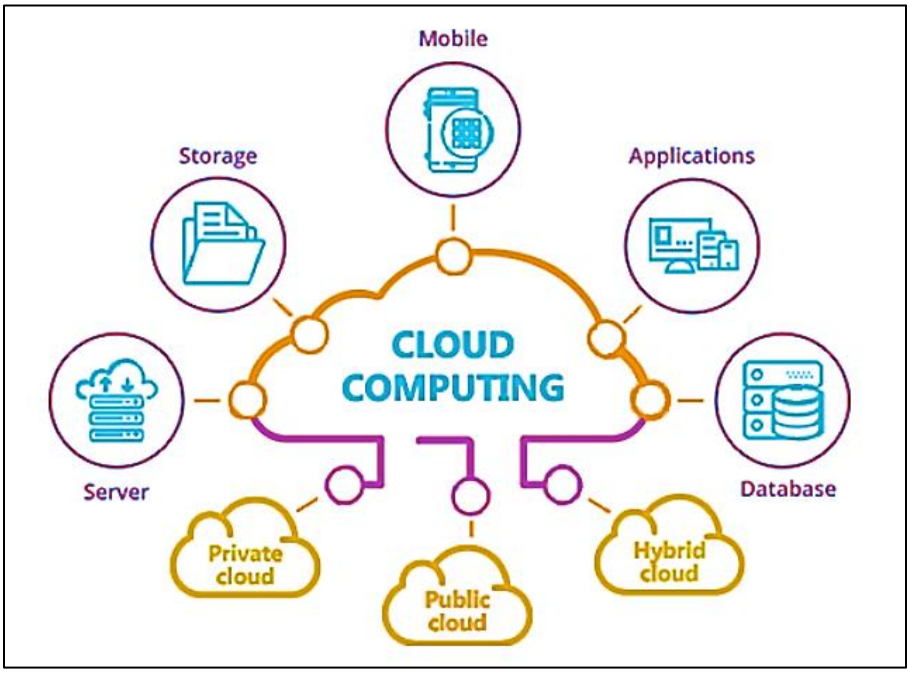

Figure 4: Cloud Computing Frameworks (*Adapted from* *https://www.networksunlimited.com/cloud-computing-trends-for-2019/*)

iii. *Augmented Reality (AR)*

Augmented Reality (AR) is an enhancement or improvisation of the real physical image upgraded through the use of digital visualisation, sound engineering and other sensory stimulus delivered through the technology. Among the popular AR applications are AcrossAir, Google Sky Map, Layar, Lookator, SpotCrime and PokemonGo.

Augmented Reality (AR) can be categorised into (1) Augmented Reality in 3D viewers, (2) Augmented Reality in Browsers, (3) Augmented Reality Games and (4) Augmented Reality GPS (Anurag, 2017). Augmented Reality in 3D viewers allows the users to put life-size 3D models in their environment with or without the use of trackers. Trackers are the simple images of 3D models that can be linked to Augmented Reality. Examples include AUGMENT and Sun Seeker. The AR browsers can enhance users' camera display with contextual information. For example, when someone points his or her smartphone at a building, its history or estimated value will be displayed. Examples for AR browsers are Argon4 and AR Browser SDK.

AR Gaming software creates mesmeric gaming experiences that use your actual surroundings. For instance, Pokémon Go, Parallel Kingdom, Temple Treasure Hunt, Real Strike and Zombie Go. AR GPS is generally an application in smartphones that include Global Positioning System (GPS) to spot the users' location and a compass to detect device orientation. Examples for this category are AR GPS Compass Map 3D and AR GPS Drive/Walk Navigation

Figure 5: Augmented Reality in Aircraft Inspection and Maintenance (*Adapted from* https://www.ptc.com/en/technologies/augmented-reality)

iv. *Simulation*

Simulation is a model or representative of a process using computer technology to develop the users' understanding. For example, the operation of an aircraft simulation for the training purposes of new pilots before handling the real aircraft. The computer model mimics the operation of any real application system. The best simulation can help the organisations to estimate better Return of Investment (ROI) before it can be initiated. Besides, simulation also provides a free risk environment to avoid risk on product standards, cost, time and people's life

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(Restart 4.0, 2021). Practically, the correct simulation model with the right data would enable organisations to predict future outcomes.

Today, many industrial facilities that concern with reducing the risk and optimising the scheduling processes have implemented industrial 4.0 technologies to improve overall productivity. This will leverage the digital twins and simulation modelling to accomplish the whole process to produce outstanding throughput.

Figure 5: Simulation allows manufacturers to develop the perfect design before the new parts are finalised and invested

v. *Robotic Automation*

Innovations of robotics, automation and artificial intelligence (AI) are the main concern for Industrial Revolution (IR) 4.0 in the manufacturing industry. Robots are generally taking place the repetitive tasks, which encouraged the workers to focus on more exclusive and intensive tasks. The number of new robots created is increasing by approximately 14% throughout the years (Polly, 2022). Factories prefer futuristic robots and humans working side-by-side to meet the global productivity demands. This is the new paradigm of manufacturing that should be prepared by all industries. AI is expected to increase the productivity of the labour by up to 40% by the year 2035.

According to research, 57% of workers indicated that they have shown interest to increase productivity by implementing automation and robots in the working environment. Furthermore, the implementation of robots will create new job opportunities and allowing employers to hire more staff in future (Polly, 2022).

For example, robot technology is currently applied at restaurants to make and send orders to the customers. The business could save its cost by employing many workers and spaces in the restaurants. In addition, it could reduce human error whenever taking orders from the customers.

Figure 6: Pizza Hut introduces the robots to greet and take orders from the customers

vi. *System Integration*

System integration is involved in system engineering and information technology fields. It combines various application systems and software packages to create larger and comprehensive systems. The system integration works cohesively in a coordinated and unified manner at optimum operation and occupies all requirements at the strategic management. The systems that have been integrated should be up to date and working properly is one of the main challenges in the system integration process for IR 4.0 (Automation.com, 2015). Another concern is to ensure that the database is secure from cyber threats and attacks besides avoiding any malicious activity.

The following Figure 7 shows a system named MyATP that integrates the systems from Research Management Systems, Publication Management Systems, Consultation Management Systems and Training Information Systems in a single integrated platform for appraisal or staff promotion. The system helps the panel to decide those who deserve a good appraisal or are suggested for the promotion.

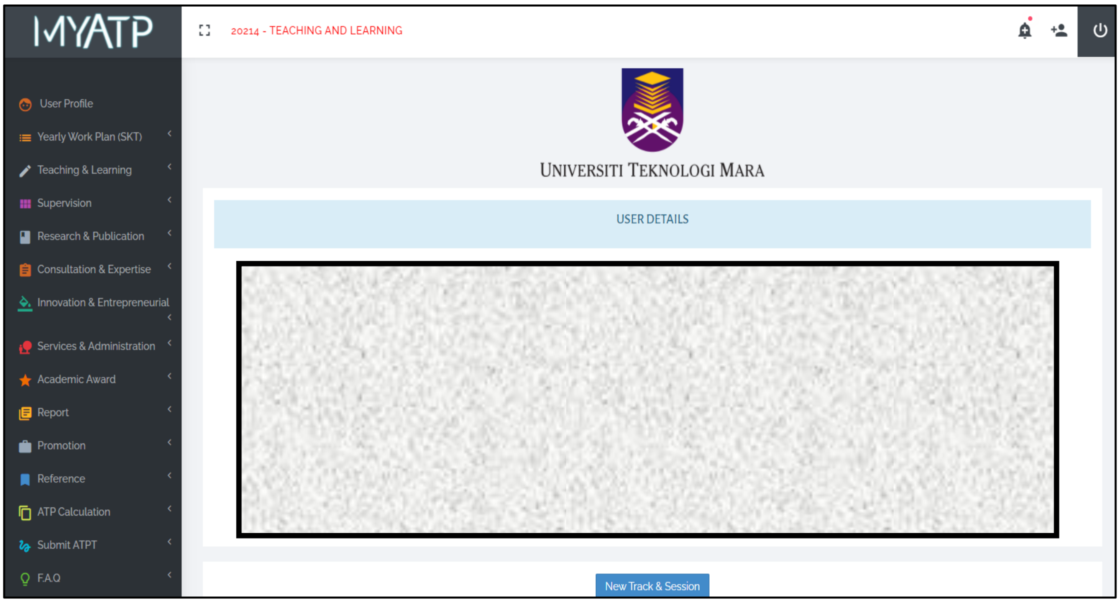

Figure 7: The MyATP system that integrates various existing systems on a platform for appraisal and staff promotion

vii. *Additive Manufacturing (AM)*

Additive manufacturing (AM) technology offers the ability to produce products with lower cost, shorter time of production, less energy and material waste needed during the manufacturing process. The AM promotes the integration of smart technologies and production systems. The manufacturers can innovate complex parts and hence reduce the inventory spaces and transport distances. Furthermore, additive manufacturing encourages making products based on users' demand and even reduces the supply chains (Zimmerman, 2018). AM requires continuous and effective communication between the devices, machines and robots with the existence of adequate digitisation and smooth manufacturing activities.

Additive manufacturing (AM) is commonly applied in the healthcare and aerospace sectors. For example, in the healthcare sector, bioprinting is understood as the production of customising human organs and transplants. Bioprinters artificially construct living tissues by outputting living cells layer upon layer in 3-D structures. Bio-printed tissues are already used in drug toxication tests nowadays, saving money and the health of test subjects during clinical trials. The second sector is the space whereby the AM is feasible for component replacement. Most of the failures at ISS (International Space Station) involve plastics and composites that could be replaced onsite by AM. Besides, AM could make the plastics and other wastes or scraps to be recycled at ISS.

Figure 8: Simplification of the production process will reduce the material and labour costs and the time required to assemble the different parts.

viii. *Big Data*

Big data is an area of integrating data from isolated systems to obtain a complete visualisation. It collects the data, analyses it and facilitates the output in proper representation. Organisations in today's eras seek to achieve business intelligence through the compilation, analysis and sharing of data across all related entities to attain business excellence (nexusintegra, 2021). Big data classifies the huge information that has been collected and organised into relevant conclusion that helps the organisations to improve the operation of the production. The improvement involves the warehousing processes, elimination of bottlenecks in the production, prediction ability on customers' demand through the internal and external analysis beyond the historical data and forecasting on the future maintenance or possible machinery failure or breakdown that affects the production.

Education institutions especially at the tertiary level have introduced the Python programming language to expose the students to the concepts of Big Data. Python has been acknowledged as the fastest-growing programming language. Since Big Data involves a lot of data analysis and scientific computing, Python provides libraries comprising packages such as numerical computing, data analysis, statistical analysis, visualisation and machine learning (nexusintegra, 2021). Nowadays, Python is considered the most popular language for software development owing to its high speed and performance.

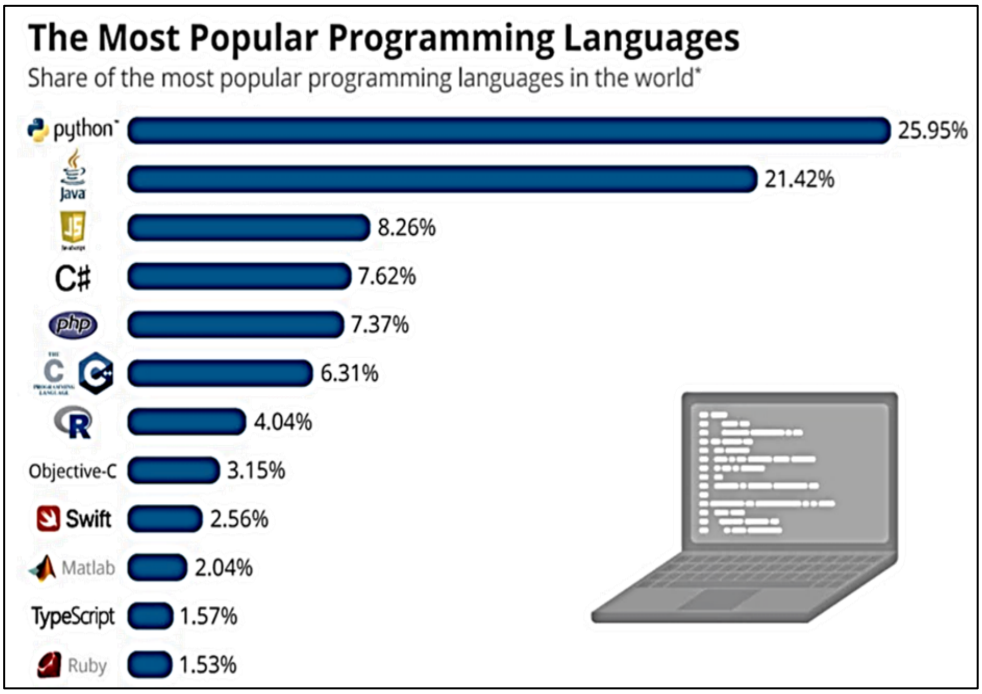

Figure 9: Python was ranked as the most popular programming language, source by PYPL, http://infographic.statista.com/normal/chartoftheday_16567_popular_programming_languages_n.jpg

ix. *Cybersecurity*

Cybersecurity is the most important element in any business to secure data and ultimately human safety. Manufacturing sector is the second most attacked and yet requires a powerful security system to secure the data (Balbix, 2021). Industries are exposed to vulnerability exploitation, malware, denial of service (DoS), device hacking and other common attack methods. There are few challenges facing the industries in the age of IR 4.0; for instance, every connected device represents the potential risks, the isolated systems are exposed to cyber-attack and visibility is very poor across the isolated environment and different systems.

The manufacturing industry is currently emphasising digital transformation, in which Cyber-Physical Systems (CPS) combine physical components and digital networks to revolutionise the way companies automate processes and share information. Besides, the smart factory's combination of virtual and physical systems makes interoperability and real-time capability possible. Digital transformation ensures the implementation of a proper security system as the key success factor for Industrial Revolution (IR) 4.0.

Conclusion

Industrial Revolution (IR) 4.0 is the main concern of the Malaysian government to move at par with other world-class countries. The government has spent a lot of money, especially in the education and manufacturing sectors to make sure that the people and industries are ready with these new trends and technologies.

Hopefully, the explanation on IR 4.0 elements will give an overview and sprouting of ideas to instructors for new applications, pedagogy and teaching style innovations of e-learning to improve the teaching skills and effective teaching delivery to learners.

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