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INDUSTRY 4.0: A REVIEW ON INDUSTRIAL AUTOMATION AND ROBOTIC

Mohd Aiman Kamarul Bahrin*, Mohd Fauzi Othman, Nor Hayati Nor Azli, Muhamad Farihin Talib

Centre for Artificial Intelligence and Robotic, Universiti Teknologi Malaysia, Kuala Lumpur, Malaysia

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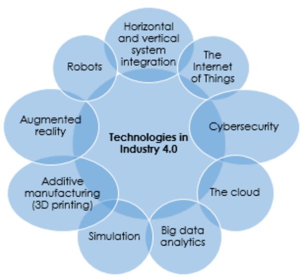
*Corresponding author
maiman5@live.utm.my

Graphical abstract



Abstract

Industry 4.0 is the fourth industrial revolution that was first introduced in Germany. This paper presents a review on the advances of robotic and automation technology in achieving industry 4.0. Many companies, research centers, and universities acknowledge that robotics and automation technology is the basis of industrial manufacturing and an important driver for Industry 4.0. Hopefully, from this report, engineering students would be exposed to new inventions of technology revolution as well as to create the business mind for a better future.

Keywords: Industry 4.0; robotics and automation; Internet of Things (IoT) power; smart factories and smart production

1.0 INTRODUCTION

The industrial sector is important to every country's economy and remains the driver of growth and employment. Industry, which in this context focuses on manufacturing, provides added value through the transformation of materials into products [1]. The term "Industry 4.0" became publicly known in 2011, when an initiative called "Industry 4.0" where an association of representatives from business, politics, and academia promote the idea as an approach to strengthen the competitiveness of German manufacturing industry [2]. Germany has one of the most competitive manufacturing industries in the world and is a global leader in the manufacturing equipment sector [3]. Since the German federal government announced Industry 4.0 as one of the key initiatives of its high-tech strategy in 2011, the topic of Industry 4.0 has become famous among many companies, research centers, and universities. Numerous academic publications, practical articles, and conferences have discussed this topic [2]. The German Federal Government presents Industry 4.0 as a new, emerging structure in which manufacturing and logistics systems in the form of Cyber-Physical Production Systems (CPPS) intensively use the globally available information and communications network for an extensively automated exchange of information and in which production and business processes are matched [4].

As the term "Industry 4.0" is not well-known outside the German-speaking area [2], it is worth looking at comparable ideas from a global perspective. Some commentator promotes a similar idea under the name of cyber physical systems, smart factory, smart production, machine-to-machine, advanced manufacturing, internet of things, internet of everything or industrial internet [5]. Industry 4.0 or fourth industrial revolution also refers to the next phase in a digitization of the manufacturing sector where the Internet of Things (IoT) looks to play a huge role that have the potential to feed information into it and add value to manufacturing industry to realize a low-volume, high-mix production in a cost-efficient way [1]. It also involves the management and organization of the entire value chain process of the manufacturing industry. Various organizations have been advocating Industrial Internet of Things and Industry 4.0 concepts to create smarter factories [3]. Meanwhile, according to [6], the idea of Industry 4.0 includes a wide variety of devices, from smartphones, gadgets, televisions and watches to household appliances, which are becoming ever more flexible and intelligent. The devices are increasingly able to communicate with one another or to data sources via the Internet. According to forecasts of analysts at Gartner [7], 26 billion "things" will be connected to the Internet in the year 2020. Thus, based on the wide literature on the topic robotic Industry 4.0, the goal is mainly to develop a smart factory in which products are able to find their own way through production and establish alternatives in case of disturbances, as a technological basis serving cyber-physical systems and the "Internet of Things and Services".

2.0 HISTORY OF INDUSTRIAL REVOLUTION

The first mechanical loom from the year 1784 until now which is exactly 232 years ago; there are four stages in the ongoing process called the Industrial Revolution. The first revolution occurred towards the end of the 18th century which was mechanical production on the basis of water and steam. The second Industrial Revolution at the beginning of the 20th century happens during the introduction of conveyor belts and mass production, to which the names of icons such as Henry Ford and Frederick Taylor are linked. The third revolution takes place in the digital automation of production by means of electronics and information technology (IT) system. Today, the industrial landscape is again being transformed to the fourth stage with the rise of autonomous robots, contemporary automation, cyber-physical systems, the internet of things, the internet of services, and so on. Industrial robots, which are one of the key drivers in Industry 4.0, have evolved considerably since the last decades of the 20th century. They are becoming more productive, flexible, versatile, safer, and collaborative and are thus creating an unprecedented level of value in the entire ecosystem. Smart factories, which will be at the heart of Industry 4.0, will take on board information and communication technology for an evolution in the supply chain and production line that brings a much higher level of both automation and digitization. It means machines using self-optimization, self-configuration and even artificial intelligence to complete complex tasks in order to deliver vastly superior cost efficiencies and better quality goods or services .

3.0 TECHNOLOGY OF INDUSTRY 4.0

Industry 4.0 is a new area where the Internet of things alongside cyber-physical systems interconnect in a way where the combination of software, sensor, processor and communication technology plays a huge role for making "things" to have the potential to feed information into it and eventually adds value to manufacturing processes. Industry 4.0 ultimately aims to construct an open, smart manufacturing platform for industrial-networked information applications. The hope is that it will eventually enable manufacturing firms of all sizes to gain easy and affordable access to modelling and analytical technologies that can be customized to meet their needs. The concept Industry 4.0 is best defined by the project's "smart factory" through the merging of the virtual and physical worlds through cyber-physical systems and the resulting fusion of technical and business processes [1]. The industrial manufacturing life cycle becomes orientated towards the increasing individualism of customer requirements and encompasses: the idea and the order for development and production, the distribution of products plus recycling, and furthermore including all related Services. The interconnection of human beings, objects and systems leads to dynamic, real time optimized and self-organized inter-company value creation systems which are evaluated and optimized using criteria such as costs, availability and resource efficiency. Industry 4.0 emphasizes the idea of consistent digitization and linking of all productive units in an economy. There are several technological areas that underpin Industry 4.0, which are horizontal and vertical system integration, the internet of things, cybersecurity, the cloud, big data analytics, simulation, additive manufacturing (3d printing), augmented reality, and robot [8]. The figure below shows the technologies related to Industry 4.0

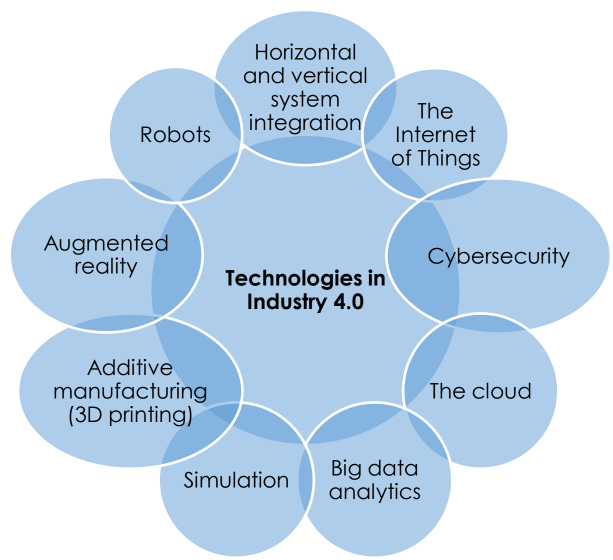


Figure 1 Technologies Related to Industry 4.0

In Industry 4.0, the horizontal and vertical system integration among companies, departments, functions, and capabilities will become much more cohesive, as cross-company, universal data-integration networks evolve and enable truly automated value chains. The Industrial Internet of Things will also enrich more devices with embedded computing and will be interconnected using standard technologies. This allows field devices to communicate and interact both with one another and with a more centralized controller, as necessary. It also decentralizes analytics and decision making, enabling real-time responses.

Reliable communications as well as sophisticated identity and access management of machines and users is important for industry 4.0 to address the issue of cybersecurity threats which increases dramatically with the increased connectivity and use of standard communication protocols.

As the performance of technologies improves, machine data and functionality will increasingly be deployed to the cloud, enabling more data-driven services for production system. More production-related undertakings in Industry 4.0 will require increased data sharing across sites and company boundaries.

Big data and analytics enables the collection and comprehensive evaluation of data from many different sources and customer to support real-time decision making, optimizes production quality, saves energy, and improves equipment service.

Simulations will leverage real-time data to mirror the physical world in a virtual model, which can include machines, products, and humans. This allows operators to test and optimize the machine settings for the next product in line in the virtual world before the physical changeover, thereby driving down machine setup times and increasing quality.

Additive manufacturing methods will also be widely used in Industry 4.0 to produce small batches of customized products that offer construction advantages, such as complex, lightweight designs. High-performance, decentralized additive manufacturing systems will reduce transport distances and stock on hand. Though the systems are still in infancy, companies will make much broader use of it towards industry 4.0.

Augmented-reality-based systems can support a variety of services, such as selecting parts in a warehouse and sending repair instructions over mobile devices.

Robots are becoming more autonomous, flexible, and cooperative. Eventually, they will interact with one another and work safely side by side with humans and learn from them. These robots will cost less and have a greater range of capabilities than those used in manufacturing today.

4.0 ROBOT IN INDUSTRY 4.0

Robots play an important role in modern manufacturing industry. The number of multipurpose industrial robots developed by players in the Industry 4.0 in Europe alone has almost doubled since 2004 [9]. An essential face of Industry 4.0 is autonomous production methods powered by robots that can complete tasks intelligently, with the focus on safety, flexibility, versatility, and collaborative. Without the need to isolate its working area, its integration into human workspaces becomes more economical and productive, and opens up many possible applications in industries. More industrial robots are evolving with the latest technological innovation to facilitate the industrial revolution. Smart robots will not only replace humans in simply structured workflows within closed areas. In Industry 4.0, robots and humans will work hand in hand, so to speak, on interlinking tasks and using smart sensor human-machine interfaces. The use of robots is widening to include various functions: production, logistics, and office management (to distribute documents) and they can be controlled remotely. If a problem occurs, the worker will receive a message on his mobile phone, which is linked to a webcam, so he can see the problems and give instructions to let the production continue until he comes back the next day. Thus, the plant is operating 24 hours/day while workers are only there during the day [9].

Several robots have been introduced with the latest technology to be the pioneer in Industry 4.0. Kuka LBR iiwa is a lightweight robot for industrial applications that is designed for safe close cooperation between human and robot on highly sensitive tasks. Iiwa which stands for intelligent industrial work assistant can learn from its human colleagues and can independently check, optimize, and document the results of its own work while connected to the cloud [10]. Bosch also introduces the APAS family robot system which includes APAS assistant, APAS inspector, and APAS base for an agile and flexible production concepts based on quickly and easily retooled production systems [11]. The robot features mobile, intrinsically safe, networked and configurable process modules which can be adjusted to new tasks by using the dialog-controlled user interface. The advanced collision avoidance system makes it safe for working together with humans. Nextage robots from Kawada Industries are an evolution from mere equipment to becoming a partner in parts assembly lines. Its overall design includes a "head" with two cameras, a torso, two 6-axis arms, and a mobile base, a flexible software GUI. Its advance stereo vision with image recognition system allows it to ascertain object distance and attain 3D coordinates with high precision. The accompanying open source software provides superb visibility and usability, making the operation and instruction of Nextage easy and flexible. There are two versions of the robot, one for the industry and the other for research. The dual-arm YuMi robot is the first collaborative robot from ABB. It features an advanced vision system, flexible hands, parts feeding systems, sensitive force control feedback, and state-of-the-art robot control software that allows for programming through teaching. Along with the built-in Safety function, it is designed to work side-by-side with humans. Several other robot models developed by various companies in keeping up with the trend is listed in Table 1 below.

Table 1 The robot application that evolve towards Industry 4.0

No	Model	Company	Description
1	Baxter	Rethink Robotics	Baxter, the world's first interactive production robot, is particularly well-suited for a wide range of packaging applications
2	Sawyer	Rethink Robotics	The revolutionary new high performance collaborative robot designed to execute machine tending, circuit board testing and other precise tasks that are impractical to automate with conventional robots
3	Roberta	Gomtec	Roberta is a light, adaptable, and inexpensive 6-Axis industrial Robot. It was specifically developed for small and medium-size enterprises which are focused on flexible and efficient automation
4	UR series	Universal Robots	UR- 5 is a highly flexible robot arm and ideal to optimize low-weight collaborative processes, such as: picking, placing and testing
5	CR-35iA	Fanuc	The CR-35iA robot seems to target integration with automotive assembly lines, machine tending applications, metalworking and packaging and more
6	BioRob Arm	Bionic Robotics	The lightweight BioRob robot has been certified safe for use in close proximity with humans without requiring further protective measures to be undertaken
7	P-Rob	F&P Personal Robotics	F&P provides all-in-one robotic solutions leveraging expertise in arm and effector technologies as well as artificial intelligence
8	Speedy-10	Mabi Robotic	The "flexible manufacturing" often publicized today is the rationale for this development and it is based on a lightweight design with excellent damping characteristics
9	PF400	Precise Automation	PF400 used by customers with little automation experience, yet powerful and fast enough to support light duty assembly operations

5.0 INTERNATIONAL ROBOTIC ORGANIZATIONS IN INDUSTRY 4.0

Various organizations and key players have substantial research departments which support product development and automation of manufacturing processes, while also marketing their know-how to other industrial enterprises or providing platforms for 'smart' services for third parties. This can further stimulate the implementation of Industry 4.0. The table below shows the organizations that are interested in the robotic industry of Industry 4.0.

Table 2 The organizations that interest in revolution industry 4.0

No	Organization	Description
1	Industry-Science Research Alliance	The Industry-Research Alliance is an advisory group which brings together leading representatives from science and industry to accompany the High-Tech Strategy of interministerial innovation policy initiatives
2	Acatech	Acatech supports policy-makers and society, providing qualified technical evaluations and forward looking recommendations and support knowledge transfer between science and industry, and encourage the next generation of engineers
3	SmartFactoryKL	SmartFactoryKL works as a pioneer for the technology transfer of key aspects of Industry 4.0 into practice
4	German Research Center for Artificial Intelligence (DFKI)	The vision of DFKI is based on cyber physical systems, combining mechanical systems with electronics to connect everything together where the different modules in the factory could potentially drive themselves around to allow factories to alter the production line

5	Institute for Management Cybernetics, RWTH Aachen University	This institute explore and develop solutions for economic and technological questions in interdisciplinary teams. The Industry 4.0 project which is ProSense is to achieve production control on the basis of cybernetic support systems and sensors, in order to support decision-makers within production planning and control
6	Platform Industry 4.0	The main objective of the Platform is the development of technologies, standards, business and organizational models and their practical implementation
7	Industrial Internet Consortium (IIC)	The goal of the IIC is to accelerate the adoption and deployment of Industrial Internet applications through technology test-beds, use cases and requirements development [12]
8	Siemens	Siemens produces custom Programmable Logic Controls (PLCs) in a state-of-the-art 'smart factory' where product management, manufacturing and automation systems are integrated [13]
9	W3C	The World Wide Web Consortium (W3C) is an international community that develops open standards to ensure the long-term growth of the Web. W3C Standards as a Basis for the Project of the Future Industry 4.0
10	OPC Foundation	The mission of the OPC Foundation is to manage a global organization in which users, vendors and consortia collaborate to create data transfer standards for multi-vendor, multi-platform, secure and reliable interoperability in industrial automation
11	Fraunhofer IAO	The Fraunhofer IAO* has been helping shape the INDUSTRIE 4.0 project since as early as 2011 as part of activities carried out by the Industry-Science Research Alliance [1].
12	Google	Google Glass as a new concept for machine operation which were primarily developed for the consumer sector, integrate among other things a head-up display for information plus a digital camera. Google Glass also be used in the industrial environment as a supplement for operation and observation in production
13	Intel	Intel is at the forefront of developing new generation low-power chips for connected IoT devices. Intel R&D centers (so called Intel Open Labs) and a number of industry co-operations (e.g., Intel and Kuka's PC-based robot-controllers) lay the foundation of Intel's IoT push. Moreover Intel is targeting startups and developers
14	Microsoft	Microsoft has teamed up with leading robotics manufacturer Kuka to create a self-standing robot that can work on factory assembly lines
15	IBM	IBM is a globally integrated technology and consulting company headquartered in Armonk, New York. IBM is focused on five growth initiatives - Cloud, Big Data and Analytics, Mobile, Social Business and Security
16	Bosch Rexroth	Bosch Rexroth's realistic assembly line manufactures individual products fully automatically and economically

6.0 INDUSTRIAL ROBOTIC POTENTIAL IN MALAYSIA

Under the Eleventh Malaysia Plan, which is a five-year comprehensive blueprint prepared by the Economic Planning Unit (EPU) of Malaysia, the government aims to raise productivity and reduce dependency on inputs from capital and labor. One of the important solutions is to raise industrial productivity, where there will be greater adoption of automation and upgrading of skills. The role of industrial associations will also be further strengthened to deal with global competition through smart partnerships with other industrial associations in target export markets [14].

Automation and robotic industry in Malaysia has been implemented since 1983 by ex-prime minister Tun Dato' Seri Dr Mahathir bin Mohamad when he introduced the national car manufacturer, Proton, that was first established as the sole national car company until the advent of Perodua in 1993 . Despite the long involvement of automation and robotic in manufacturing, the idea of Industry 4.0 in Malaysia is mostly influenced by foreign companies such as KUKA and ABB. Very large manufacturing companies and multinational groups already consider this topic as very important. Small and medium enterprises (SME) do not yet appear to consider industry 4.0 to be of great relevance to them, although these companies are most likely to be the big winners from the shift. SME companies are often able to implement the digital transformation more rapidly because they can develop and implement new IT structure from scratch more easily. Very large manufacturing companies and multinational groups, by contrast, have more complexity to deal with in terms of their existing, organically grown structures.

Malaysian government agencies have come up with several initiatives to encourage the adoption of latest technology to local industry. The Malaysian Industry-Government Group for High Technology (MIGHT) is introduced to address the country's needs in response to the effects of globalization and trade liberalization on future economic growth through the accelerated use of high technology. Under this initiative, programs and activities will include building strategic partnerships and alliances, technology acquisition and nurturing, capacity building as well as strengthening the growth of these sectors through policy interventions and flagship programs. Malaysia aims to be at the forefront of the next generation of advances in science and technology through the newly set-up Global Malaysia-Korea Robotics Collaboration and Development Program where both parties have agreed to exchange robot human capital development programs, to undertake robot standardization cooperation, to launch robot exhibition and international cooperation [15]. MIMOS, which is Malaysia's national R&D centre in ICT, are doing collaboration with China on research and development on smart manufacturing technology [16].

Therefore, the development of automation and robotic industry has the potential to lead Malaysia towards industry 4.0 through key initiatives by government and industry player alike.

7.0 IMPACT OF ROBOTIC INDUSTRY 4.0

The conceptual Industry 4.0 have a high impact and wide range of change to manufacturing processes, outcomes and business models. It allows mass customization, increase of productivity, flexibility and speed of production and improvement on quality product. This mass customization will allow the production of small lots even as small as single unique items due to the ability of rapidly configure machines to adapt to customer-supplied specifications and additive manufacturing. This flexibility also encourages innovation, since prototypes or new products can be produced quickly without complicated re- tooling or setup of new production lines. Thus it can produce one product and many variants, with a decrease in inventory by using Industry 4.0 technologies [8]. The speed with which a product can be produced also improved where digital designs and virtual modelling of manufacturing process reduce the time between the design of a product and its delivery. In Germany, data-driven supply chains can speed up the manufacturing process by an estimated 120% in terms of time needed to deliver orders and by 70% for the time to get products to market [17].

Integrating product development with digital and physical production has been associated with large improvements in product quality and significantly reduced error rates. Data from sensors can be used to monitor every piece produced rather than using sampling to detect errors, and error-correcting machinery can adjust production processes in real time. This data can also be collected and analyzed using 'big data' techniques to identify and solve small ongoing problems. The rise in quality plays an important role in reducing costs and hence increasing competitiveness. According to [18], the top 100 European manufacturers could save the costs of scrapping or reworking defective products if they could eliminate all defects.

Productivity can also increase through various Industry 4.0 effects. By using advanced analytics in predictive maintenance programs, manufacturing companies can avoid machine failures on the factory floor and results in downtime cut and increase production. Some companies will be able to set up 'lights out' factories where automated robots continue production without light or heat after the staff has gone home. Human workers can be used more effectively, for those tasks which are really important.

It is easier to make money today with fewer workers rather than a quarter of a century ago. In a book on the Fourth Industrial Revolution handed to each of the delegates at World Economic Forum [13], Schwab compares Detroit in 1990 with Silicon Valley in 2014. In 1990 the three biggest companies in Detroit had a market capitalization of $36 billion, revenues of $250 billion and 1.2 million employees. In 2014, the three biggest companies in Silicon Valley had a considerably higher market capitalization ($1.09 trillion) generated roughly the same revenues ($247 billion) but with about 10 times fewer employees (137,000). Robotic in Industrial application has substantial economic impact where increasing of productivity can drive economic growth. A recent study estimates that these benefits will have contributed as much as 78 billion euros to the German GDP by the year 2025 [2].

8.0 CONCLUSION

This paper reviews the concept trend of robotic technology in Industry 4.0 or a similar idea. Since the advent of Information and communication technologies (ICT), economies of countries around the world increases dramatically as companies can compete on a global scale to grab the opportunity that presents. German intends to become the leading market for Industry 4.0 solutions lead the industry 4.0 revolution since 2011 to materialize its high-tech vision so that many of the company, organization and researcher take this opportunity to advance their knowledge and technology. The fourth industrial Revolution will be based on cyber-physical systems, the Internet of Things and Internet of Service. More companies and nations are joining the movement with different approach so as to be competitive in order to benefit from the productivity and economic gains it provides. Although industry 4.0 covers a very wide application area in the manufacturing industry, the trend is quickly materialized with the emergence of new robotic and automation product innovation that is tailored for industrial revolution.

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