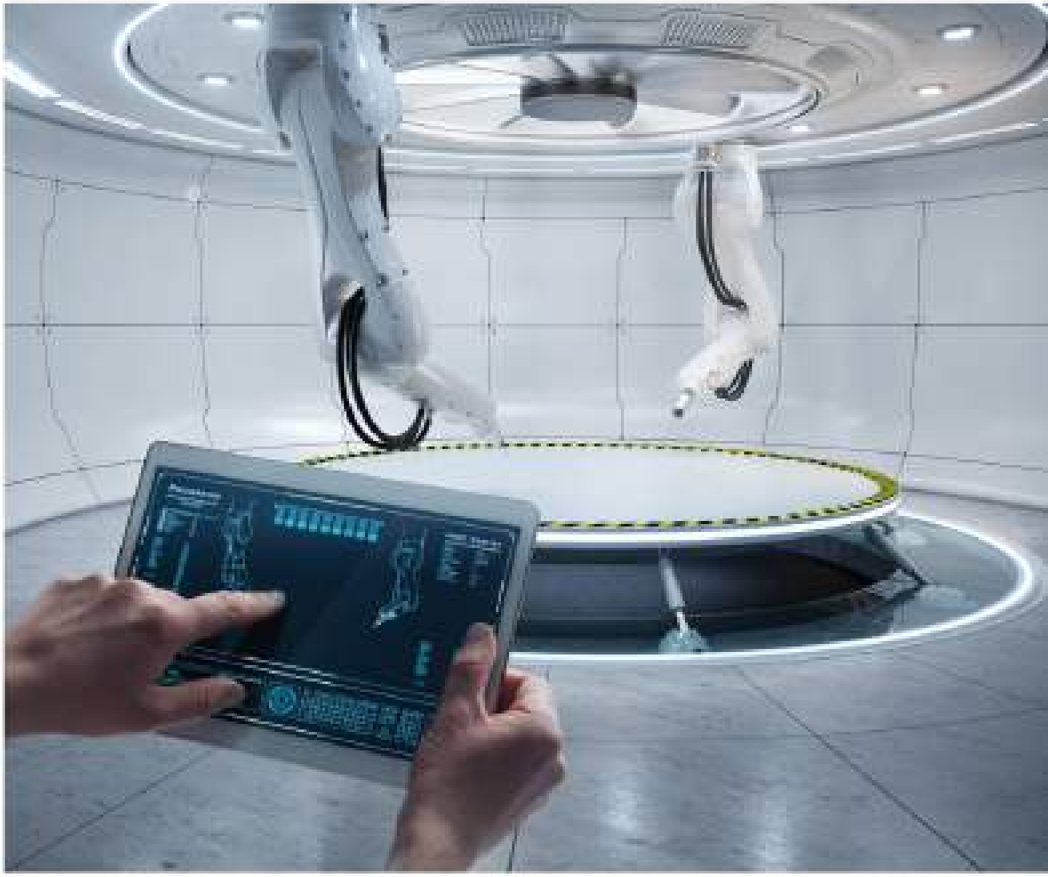
The Institution of Engineering and Technology

# The Nine Pillars of Technologies for Industry 4.0

Edited by
Wai Yie Leong, Joon Huang Chuah and Boon Tuan Tee



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# The Nine Pillars of Technologies for Industry 4.0

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# Foreword

Industry 4.0 refers to the current trend of automation and data exchange in manufacturing technologies, also called Intelligent or Smart Manufacturing. There is an increasing number of organizations and countries where Industry 4.0 is becoming adopted including the United Kingdom (Industry 4.0 and the work around 4IR), the United States, Japan, China and the European Union. Several research organizations, with a leading role for the Fraunhofer Institute, are pushing a reference architecture model for secure data sharing based on standardized communication interfaces. The nine pillars of technology that are supporting this transition include: the internet of things (IoT), cloud computing, autonomous and robotics systems, big data analytics, augmented reality, cybersecurity, simulation, system integration and additive manufacturing. A key role is played by Industrial IoT with its many components (platforms, gateways, devices) but many more technologies play a role in this process including cloud, fog and edge computing, advanced data analytics, innovative data exchange models, artificial intelligence, machine learning, mobile and data communication and network technologies, as well as robotics, sensors and actuators. Over the IoT, cyber-physical systems communicate and cooperate with each other and with humans in real-time both internally and across organizational services in the value chain. Within smart factories, cyber-physical systems monitor physical processes, create a virtual copy of the physical world and make decentralized decisions. The aim of this edited book is to focus on the nine pillars of technology including innovative research, challenges, strategies and case studies.

Advances in science and technology continuously support the development of industrialization all over the world. The First Industrial Revolution used water and steam power to mechanize production, the Second used electric power to create mass production and the Third used automation for the manufacturing line. Now a Fourth Industrial Revolution, the digital revolution, is characterized by a fusion of technologies that is blurring the lines between the physical, digital and biological spheres. There are three reasons why today's transformations represent not merely a prolongation of the Third Industrial Revolution but rather the arrival of a Fourth and distinct one: velocity, scope and systems impact. The speed of current breakthroughs has no historical precedent. When compared with previous industrial revolutions, the Fourth is evolving at an exponential rather than a linear pace. Moreover, it is disrupting almost every industry in every country. And, the breadth and depth of these changes herald the transformation of entire systems of production, management and governance. The design principles of Industry 4.0 such as virtualization, interoperability, decentralization, service-oriented approaches, real-time capabilities and modularity all play a key role in the radical changes facing industry. In this book series, we describe the advantages of intelligent manufacturing systems and discuss how they will benefit the manufacturing industry by increasing productivity, competitiveness and profitability. (Benefits: enhanced productivity through optimization and automation, real-time, better quality products, sustainability, personalization and customization for consumers, and improved scalability and agility.)

In this book series, the nine pillars of technology that are supporting this transformation have been introduced: the IoT, cloud computing, autonomous and robotics systems, big data analytics, augmented reality, cybersecurity, simulation, system integration and additive manufacturing.

Technologies and Industry 4.0 are about reducing complexity and processes and add value. However, while business processes are changing rapidly, industries and manufacturers are struggling to exploit the full potential of digitization. From both a strategic and technological perspective, the Industry 4.0 roadmap visualizes every further step on the route towards an entirely digital enterprise. Many case studies have been discussed in this book series, which aims to benefit and create impact to industry players, scientists, academicians, researchers and manufacturers.

# *Chapter 4*
# Virtual and augmented reality in Industry 4.0

*Mohankumar Palaniswamy*[1]*, Leong Wai Yie*[2] *and Bhakti Yudho Suprapto*[3]

There was a period in our history, where industrial works used to happen manually by labors at their houses. Later, it started to happen in industries with the help of machines. The process of transferring a labor-based agrarian economy to a machine-based is called as Industrial Revolution. This transformation initially started in Great Britain during the eighteenth century, followed by European countries such as Belgium, Germany, and France and slowly started to spread across the globe. Industrial revolution was the result of development in knowledge, equipment, machineries, technologies, and tools, especially social and cultural acceptance from people and benefits arising from it. Earlier, iron, steel, and wood were the primary raw materials used widely. Steam engine, combustion engine, and electricity were available at that time. Later, due to industrial revolution, steamship, locomotive, telegraph, and radio were developed. The idea of using science for development of humankind in the name of industry or factory started taking roots.

The economic transformation that took place in Western countries from 1780 to 1850 was termed as the First Industrial Revolution [1]. Realizing the importance of science and technology, with more research, second and third industrial revolutions took place. The duration of every industrial revolution was around five decades. This was the period of mass production.

## 4.1 Industry 4.0

There is a general belief that first industrial revolution was about steam and water, second industrial revolution was about steel, and third industrial revolution was about electricity, internet, and automobiles. In contrast, fourth industrial revolution has just begun [2] (Figure 4.1). The term Industry 4.0 was put forward by the German government in 2011 at Hanover fair [1]. The term Industry 4.0 is also called as “Industrial Internet,” “Digital Factory,” “Intelligent Factory,” “Factory of Future,”

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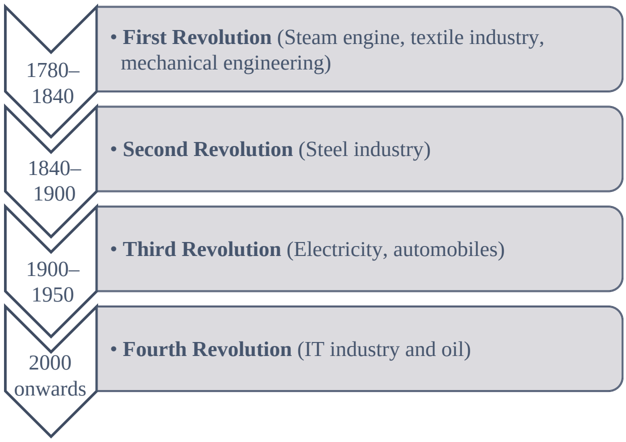


*Figure 4.1 Industrial revolutions*

and "Smart Manufacturing" by professionals [3]. Industry 4.0 or Fourth Industrial Revolution is based on internet of things (IoT), internet of services (IoS), cyber-physical systems (CPSs), and interaction and exchange of data between humans (C2C), machines (M2M), and between humans and machines (C2M) [4,5]. As the Industry 4.0 is still in its early stage, several research organizations, universities, and companies try to develop a fully automatic internet-based industry or factory, such as Siemens Amberg plant in Germany, where the 108,000 square foot factory can run and assemble components without any human input [6]. Industry 4.0 has several components such as cloud computing, CPS, IoT, system integration, additive manufacturing (AM), augmented reality (AR), virtual reality (VR), data analysis, AI robots, etc. (Figure 4.2).

Cloud computing – production-related data will be uploaded and shared in the cloud technology, where the receiving and reaction time will be few milliseconds. CPS – an advanced IT tool, which has a big storage capacity and high transmission speed. CPS provides solutions based on software-related applications while reducing the role of hardware or mechanical devices [8]. Smart products are components of CPS. It can connect between both the real and virtual world [9]. IoT – modern manufactures thought how to convert their product into a long-term revenue-providing service. It led them to IoT. IoT is the fundamental integration of smart devices, which are parts of the smart projects. For example, in a smart house, television, gaming console, and air conditioner that have an IP address can be connected to the IoT [10] and can be accessed from anywhere. Otis supplies elevators with sensors to the public, which send data to their cloud. This data is analyzed and Otis offers maintenance packages, which again generates extra revenue [11] (refer Figure 4.3). System integration – in Industry 4.0, several departments under a factory or several factories under same company become organized and interconnected with universal data integration. Additive manufacturing (AM) – with Industry 4.0, 3D printing will be widely used to manufacture customized products.

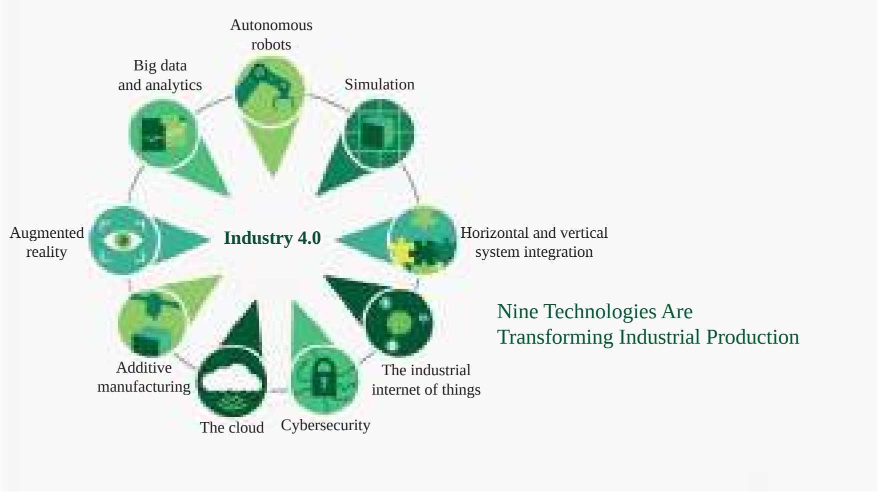


*Figure 4.2 Components of Industry 4.0 [7]*

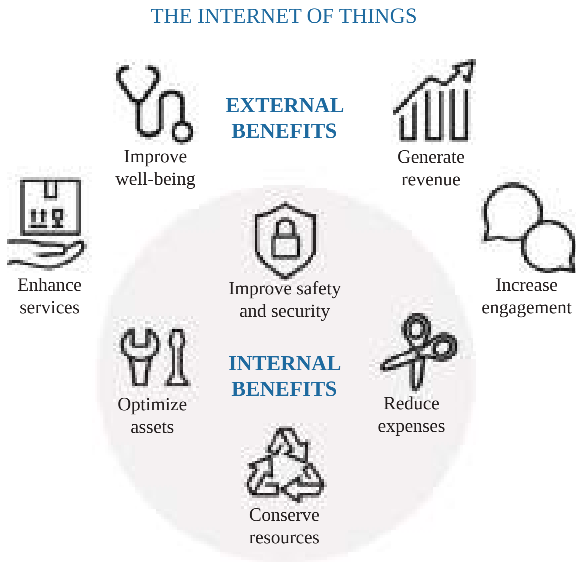


*Figure 4.3 Internet of things [12]*

AR, VR – AR- and VR-based services offer workers and operators to improve decision-making and limiting the work procedures. Data analysis – collecting and indexing data from different sources will become default in industries to support real-time decision-making. AI robots – robots will start to work with each other safely along with or without human intervention.

### *4.1.1 Augmented reality and virtual reality*

The human and machine work interference in industry should be flexible and adaptive [13]. Because of this, several industries started to adopt using AR and VR to train their workers [14]. With this training, they can (i) speed up the work or reconfigure the work, (ii) support operators, (iii) execute augmented virtuality (AV) training for compiling or constructing parts, (iv) administer depository or stockroom effectively, (v) support diagnostics in the assembly, and (vi) minimize the risk in the work setting [15]. The key technologies on AV used in the industries are display interaction, tracking positioning and registration, human–computer interaction, object detection and recognition, calibration, model rendering, analysis on 3D space, and collision detection [16–19].

Attempts on 3D simulation dates to 1930, when Stanley G. Weinbaum used a pair of goggles to watch his movie "Pygmalion's Spectacles" to undergo holographic experience. Latter AR was first introduced by computer pioneer Ivan Sutherland in 1968 [20]. He used a head mounted display (HMD) device, which was connected to a stereoscopic display from a computer. AR is a technology that overlays virtual image or information in real world. For example, adding an image or text to user display virtually in the real environment (RE). Here, RE represents surrounding of the user. The recent Pokemon GO game is a good example of AR usage [21]. In contrast, virtual environment (VE) is the surrounding completely generated by computer, where the user will not have any contact with the RE [22] (Figure 4.4). VR is a synthetic world, which may or may not look like a real world [23]. Initially, VR took over the world in 1990s by equipment such as Saga VR and Nintendo Virtual Boy. In the twenty-first century, using VR, people started to create a virtual representation of themselves called "Avatars."

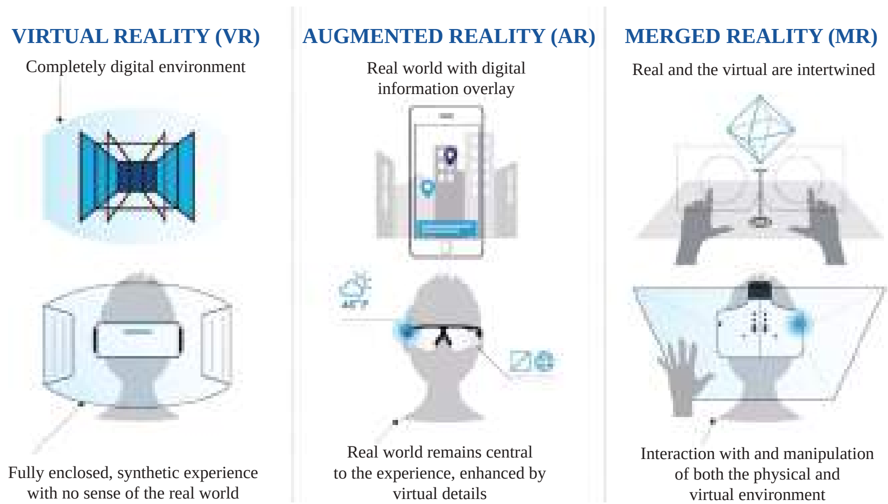


*Figure 4.4 Difference between VR, AR, and MR [24]*

#### 4.1.1.1 Programming libraries

There are several AV programming libraries used in the industries. Among them ARToolKit, ARTag, osgART, and Vuforia are commonly used. ARToolKit is an opensource tracking library. It is the most common tool used to develop AR. Hirokazu Kato first developed it in 1999. ARToolKit was further developed with ARTag. ARTag is used to simplify the virtual objects within real world. OsgART is a C++ cross-platform library. It compiles the tracking library with 3D library. Vuforia is an AR software-development kit for mobiles. It compiles computer vision, planar changes, and 3D objects in real time [25]. With the recent development of mixed reality (MR), AR and VR are more commonly used in industries to reduce their processing, training, and decision-making time. With this in mind, this chapter reviews the achievements of AR and VR, tools used for constructing reality, and their field of use in the recent times.

## 4.2 AR and VR in Industry 4.0

AR and VR are very commonly used in the manufacturing industries for the purpose of quality control in the product, training or teaching the new recruits, designing the workspace, customization according to client need, maintenance of factory, manufacturing items, and marketing.

Quality assessment, which is done in traditional method, consumes a lot of time. A conceptual idea proposed and validated by Federica Ferraguti *et al*., found that AR can be used in quality control [26]. With their approach, an operator can directly see the product if it has reached the quality specifications or any further refinements required. Factories are run not only by humans but also with machines such as robots. New theory puts forward that VR can be used for human–machine collaboration for adaptive product engineering [27].

Not only in designing, production, and quality control of a product but also in marketing the product AR and VR can be used. A 2013 study on footwear marketing used AR and VR technologies for marketing. Morenilla *et al*. [28] developed a stereoscopic vision system based on 3D+ software and footwear design. A desktop computer operating Windows 7 with i5 processor, 4GB RAM, nVidia Quadro 600 graphic card, 3dVision pack, BENQ double-frequency LED 3D monitor, and CodeGear C++ RAD Studio 2007 were used to view the footwear. To interact with the footwear, a VR glove from 5DT was used. It had five sensors for flexion and two for rotation. This single glove replaces the job done by keyboard and mouse. Different positioning of finger gestures corresponds to different view (Figure 4.5). To capture the user or consumer and view him/her in AR, a scene-capturing camera, LG Webpro 2, was used. To locate the position of foot, IR camera from Nintendo console and emitting device comprised of four LED diodes were used (Figure 4.6). After calibration and processing, final output is viewed in the monitor in real time, where the consumer is real, and the shoe is virtually developed (Figure 4.7). Using this method, consumer can see himself or herself wearing the shoes virtually.

*Figure 4.5 Glove gestures and the corresponding view [28]*

Using AR and VR, an ergonomic workplace can be set up or ergonomics of the existing workplace can be found. Ceit ergonomic analysis application (CERAA) is used in mobile or with cave automatic virtual environment (CAVE), markers, Wii remotes, and assessment forms such as rapid entire body assessment (REBA), and rapid upper limb assessment (RULA) to find the office ergonomics [29,30].

AR is used in customization of an industry or factory, based upon the need. Using product manuals or descriptions in a PDF format is old fashioned. Recent 2019 studies incorporated AR by utilizing Unity 3D, Vuforia, HMD, and HoloLens to convert paper manuals into digital texts, signs, and graphical representations [31–33]. This method helps the operator to understand and use the manual easily [34]. AR and VR are used in designing a virtual workspace environment, where the operator or mechanic can understand how the parts are assembled [35,36]. Using AR and VR, remote maintenance is also possible [37,38]. VR is particularly used for industrial application training. Instead of onsite visit and consuming working hour, a virtual representation of the industry, warehouse, and its components is beneficial and valuable in training a fresher [39,40].

A 2019 study by Perez *et al*. [41] developed a VR of the industry, mimicking the same environment along with the robots to train the operators. Generally, robot is a mechanical structure with electronics, motors, controllers, and human–

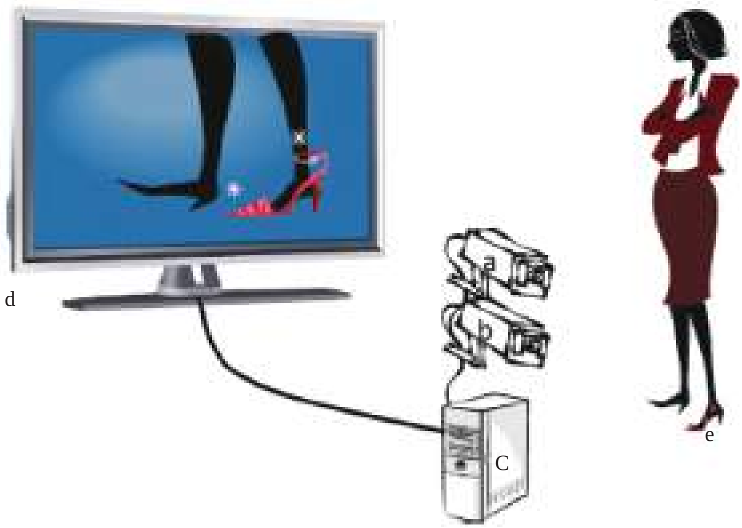


*Figure 4.6 AR prototype. (a) Scene-capturing camera, (b) IR camera, (c) computer with footwear design, (d) double-frequency LED monitor, and (e) IR LED diodes [28]*

*Figure 4.7 Final outcome [28]*

machine interface (HMI). Perez *et al*. replaced this HMI with VR, which is connected to the robot. Their proposed system consists of two robots: a real and virtual, both controlled by same controller which was paired with VR (Figure 4.8). Sensors were connected to the real robot to obtain the pose and accuracy. To develop an identical workplace environment virtually, the workplace environment was initially

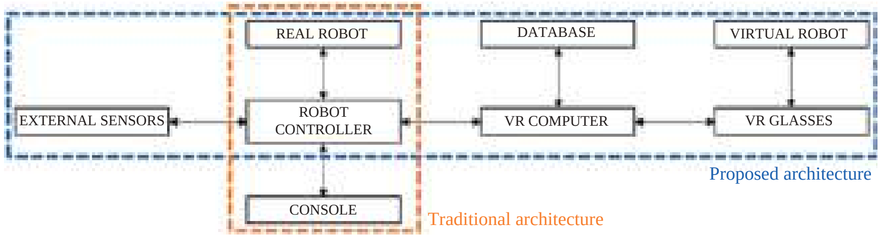


*Figure 4.8 System architecture [41]*

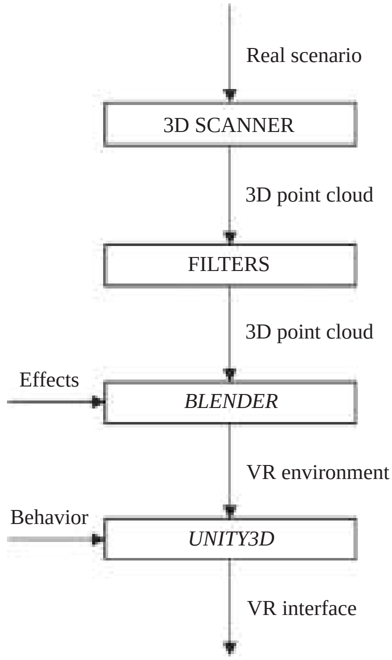


*Figure 4.9 Process to develop VR interface [41]*

scanned with FARO Focus3D HDR. The obtained 3D point cloud was processed with CloudCompare, modeled with Blender, and then processed with Unity3D to implement HMI (Figure 4.9). Using Oculus Rift and HTC Vive, the developed virtual was screened to operators for VR-simulated and VR-operated robot training (Figure 4.10). Twelve people underwent training and their feedback was recorded using questionnaire. They felt that VR training would increase efficiency of working environment.

AR, VR, and additive manufacturing are the most valuable aspects of aviation industry right now, as they play a major role in maintenance, detection of errors and safety in aircraft, and manufacturing small parts for small aircraft [42–44]. AR and

(a) (b)

*Figure 4.10 Training. (a) With real robot and (b) with virtual robot [41]*

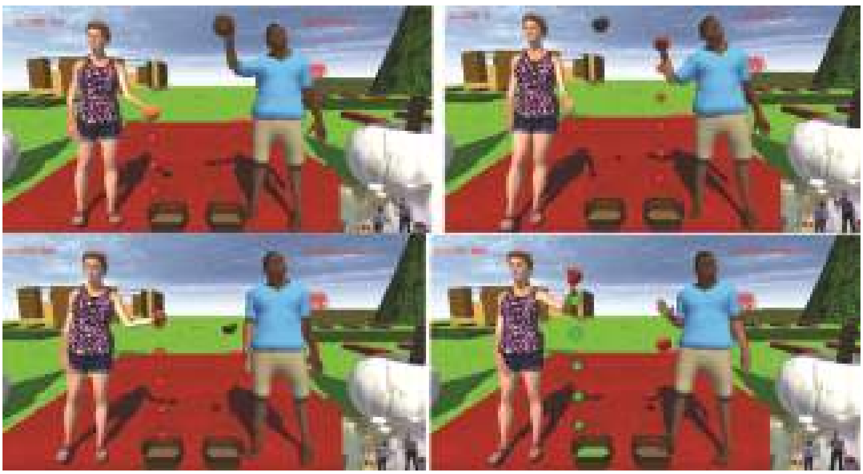

*Figure 4.11 ReHabGame session, therapist, and patient [51]*

VR technologies are used in construction and designing of buildings, machines, and robots. Particularly, AR is used in building information modeling (BIM) [45]. BIM information's provided in the software can be used during onsite visit. It can also be used latter for maintenance purpose. This in turn contributes to optimization and defect prevention [46–48].

AR and VR have revolutionized the medical field. They are utilized in analysis, rehabilitation, surgery, and treating phobias. Using leap motion sensor, IR camera, LED, and Unity 3D, hand motion analyses were performed [49]. Using Microsoft Kinect, Myo Armband, and Unity 3D, rehabilitation for stroke patients is provided. A game such as virtual environment is developed using Unity 3D, where the patients are supposed to play, such as throwing a ball or a fruit in a basket [50,51].

A 2018 study conducted by Esfahlani *et al*. [51] developed a VR-based game called "ReHabGame" to treat stroke patients. The game was developed using

*Table 4.1 Augmented and virtual reality in different fields*

| Author | Year | Field | Technology | Tool | Sample | Objective |
|---|---|---|---|---|---|---|
| Lee *et al*. [48] | 2011 | Construction – Design | VR | ARToolKit, Microsoft Vision SDK, ROBOOP, Boost, V-Collide | – | Construct a mixed reality-based digital manufacturing environment |
| Morenilla *et al*. [28] | 2013 | Marketing | AR, VR | 3D+, nVidia Quadro 600, 3D monitor, IR emitter, 5DT Virtual Glove | – | Implement AR, VR during footwear purchase |
| Fillatreau *et al*. [66] | 2013 | Industry – Maintenance | VR | Virtuose 6D Haptic Arm, CyberGlove II, ARTrack, VSL, C# | – | Framework for immersive checklist-based project reviews |
| Wang *et al*. [45] | 2014 | Construction – Maintenance | AR | Mobile, Tablet, HMD | – | Need for a structured methodology of fully integrated AR technology in BIM |
| Asgari *et al*. [46] | 2017 | Construction – Maintenance | VR | Leap Motion Controller, Myo, Nimble VR, Prio VR | – | Construction process optimization and defect prevention |
| Hui [40] | 2017 | Industry – Training | VR | Leap motion, Unity 3D, HMD, Gyroscope, Accelerometer, Nexus 6P mobile, Trinus | 10 | Compare experience and training effects in HMD-based and screen-based training |
| Giorgio *et al*. [27] | 2017 | Industry | VR | HTC Vive, Unity 3D | – | Human robot collaboration in product engineering by VR |
| Bun *et al*. [58] | 2017 | Medical – Therapy | VR | 3DS Max, EON Studio, nVisor MH60, Oculus Rift | 20 | To treat acrophobia using VR |
| Gasova *et al*. [30] | 2017 | Industry – Design | AR, VR | CERAA, Mobile | – | Ergonomic assessment in industrial environment |
| Masoni *et al*. [37] | 2017 | Industry – Maintenance | AR | AR Goggles, Tablet, Unity 3D, Vuforia | – | Provide a remote maintenance in industry 4.0 using AR |
| Eschen *et al*. [42] | 2018 | Aviation – Maintenance | AR, VR | Oculus Rift, Oculus SDK, OpenGL, Game controller, Microsoft HoloLens, KUKA Robot | – | Detection of cracks in the maintenance of aircraft engines |
| Fazeli *et al*. [49] | 2018 | Medical – Analysis | VR | Leap Motion Sensor, IR Camera, IR LED, Unity 3D | Case Study | Hand motion analysis using VR |

*(Continues)*

| | | | | | | |
|---|---|---|---|---|---|---|
| Karvouniari *et al.* [29] | 2018 | Industry – Customization, Ergonomics | VR | CAVE, VICON Bonita 3, Markers, Wii Remotes, Unity 3D, RULA, REBA | – | VR-based decision tool for exoskeleton integration in industry |
| Scurati *et al.* [32] | 2018 | Industry – Maintenance | AR | Questionnaire, Unity 3D, Vuforia, Mobile | – | Convert manuals into graphical symbols and use it in maintenance with AR |
| Shi *et al.* [50] | 2018 | Medical – Rehabilitation | VR | Kinect Sensor, Unity 3D, C# | – | VR-based user interface for the upper limb rehabilitation |
| Esfahlani *et al.* [51] | 2018 | Medical – Rehabilitation | VR | ReHabGame, Kinect, Myo Armband, Questionnaire | 20 | Rehab stroke patients using VR |
| Mourtzis *et al.* [36] | 2018 | Industry – Design, Training | AR | HoloLens, Unity 3D, CAD | 100 | Applying advanced visualization techniques in product design using AR |
| Wolfartsberger *et al.* [38] | 2018 | Industry – Maintenance | VR | Desktop PC (VR Ready), HTC Vive, Sensors, Controller. Unity 3D, 3DS Max | – | Implementation of a lightweight VR system in industrial engineering applications |
| Masood *et al.* [34] | 2019 | General – Manufacture | AR | Questionnaire, 5-point Likert scale | 365 | Factors influencing the success of implementing AR in industry |
| Gattullo *et al.* [33] | 2019 | General – Maintenance | AR | iFixit, PDF, Unity 3D, Vuforia, Questionnaire | 22 | Convert traditional text manuals to digital manuals in AR with compliance to Industry 4.0 |
| Alarcon *et al.* [44] | 2019 | Aviation – Maintenance | AR | Questionnaire, 5-point Likert scale | 56 | AR application in space product assurance and safety activities |
| Ceruti *et al.* [43] | 2019 | Aviation – Maintenance, Manufacture | AR, Additive Manufacture | Game controller, Microsoft HoloLens, HoloLens clicker | Case Study | Demonstrate that AR and AM are viable tools in aviation maintenance |
| Kwiatek *et al.* [47] | 2019 | Construction – Maintenance, Design | AR | Tablet, AR application | 61 | Impact of AR on assembly in construction |
| Wolfartsberger [35] | 2019 | Industry – Design | VR | HTC Vive, Unity 3D, 3DS Max | – | VR-based tool to support engineering design |

*(Continues)*

*Table 4.1* (*Continued*)

| Author | Year | Field | Technology | Tool | Sample | Objective |
|---|---|---|---|---|---|---|
| Perez *et al*. [41] | 2019 | Industry – Training | VR | KUKA KR500, Oculus Rift, HTC Vive, FARO Focus 3D, Blender | 12 | Replace the HMI directly with VR system which is connected with robot controller |
| Kopec *et al*. [53] | 2019 | Education – Training | VR | Proto.io, Epic Game's Unreal Engine, Unity Game Engine, HTC Vive, Mattel View | 4 | Virtual ATM training for older adults |
| Garcia *et al*. [54] | 2019 | Education – Training | VR | Unity Pro, Raspberry Pi, Oculus Rift, FESTO lab | – | Achieve a virtual training environment to teach pneumatic systems in university students |
| Roldan *et al*. [55] | 2019 | Education – Training | VR | Unity Game Engine, SteamVR, HTC Vive, Questionnaire | 20 | Training for industry operators based on VR |
| Urbas *et al*. [31] | 2019 | Industry – Customization | AR | Bluetooth-enabled Vernier Caliper, HMD, HoloLens, Vuforia, Unity Game Engine | – | Transfer of product manufacturing information from a 3D model and display the graphical presentation in AR |
| Ferraguti *et al*. [26] | 2019 | Industry – Quality Control | AR | HoloLens, Mixed Reality Toolkit, Vuforia, Xbox Controller | – | AR in quality control |
| Mourtzis *et al*. [39] | 2019 | Industry – Design, Operation | AR | Enterprise Dynamics 10, 4D Script, QR Codes, Mobile GPS | – | Operate a warehouse using AR |
| Nguyen *et al*. [56] | 2019 | Medical – Surgery | AR | Tap to Place, HoloLens Cursor | 27 | AR-assisted surgery |
| Ibanez [52] | 2020 | Education – Training | AR | IMMS survey, Questionnaire, ARGeo | 93 | Impact of AR in students' academic achievement |
| Masood *et al*. [67] | 2020 | General – Manufacture | AR | Microsoft HoloLens, Unity, Questionnaire, TCT, TLX | 11 | AR implementation in industry |
| Nguyen *et al*. [57] | 2020 | Medical – Surgery | AR | AR Roadmap | 240 | CAN for pedicle screw insertion during spine surgery |

Abbreviation: AM, additive manufacture; AR, augmented reality; BIM, building information modeling; CAD, computer aided design; CAN, computer-assisted navigation; CAVE, cave automatic virtual environment; CERAA, Ceit ergonomic analysis application; HMD, head mounted display; IMMS, instructional materials motivation survey; REBA, rapid entire body assessment; RULA, rapid upper limb assessment; SDK, software development kit; TCT, task completion time; TLX, task load index; VR, virtual reality; VSL, virtools scripting language

Unity game engine, which integrates motion / gesture capture, image processing, skeleton tracking, and IR emitter. Hardware components include only Microsoft Kinect and Thalmic Labs Mayo armband. Postural control, gestures, range of motion were tracked. ReHabGame include three main game designs: (i) reach grasp release, (ii) reach press hold, and (iii) reach press. Players reach, grasp, hold, and release virtual fruits in the virtual basket (Figure 4.11). This game involves flexion, extension, abduction, adduction, internal/external rotation, and horizontal abduction/adduction. Twenty stroke-affected patients participated in the study. Majority of the patients enjoyed the rehabilitation-based game and provided positive feedback.

Education is most important for all [68–74]. AR and VR outsmart the traditional black board and power point presentations. Irrespective of the age, AR and VR can be used to teach and train the young and old. AR is helpful for students' academic achievement [52]. VR is used in ATM training for older adults [53]. Virtual trainings are also provided to industrial operators [54,55]. A recent study developed a VR of mining process. Workers were trained and evaluated using questionnaire. A 2020 study used computer-assisted navigation (CAN) technique using AR Roadmap, Tap to Place, and HoloLens Cursor to perform spine surgery [56,57]. A VR-based study used Oculus Rift, nVisor MH60, EON Studio to treat acrophobia – the fear of height. Therapy is provided by developing a virtual high altitude scenario such as hill, tall building, and asking the patients to walk and cross the high altitude from one point to another [58]. Apart from industry, education, and medicine, AR and VR are used in other fields as well. Tourism [59,60], gaming [61], choreography [62], and customer satisfaction [63–65] are to name a few. The summary of this review is provided in Table 4.1.

## 4.3 Conclusion

This chapter assessed and reviewed the implementation of AR and VR in Industry 4.0. Researchers came up using low-cost devices and own algorithms rather than traditional commercial software such as CAVE, which cost more. Some papers proposed a conceptual theory, whereas others came up with quantitative and qualitative assessments. Their results suggest that AR and VR play a major role in minimizing the real-time decision-making and processing time. In industry-based setting, the utilization of AR and VR is more prominent. However, other than industry, the roots of AR and VR are not deep. Other fields such as education, tourism, and customer marketing have started to make use of AR and VR gradually, and it can be expected that eventually, the roots may deepen.

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