Industry 4.0 and Components in Production Enterprises

Fatih Ozturk

Abstract The globalizing world economy is constantly challenging producers with difficult competitive conditions. Manufacturer companies determine various methods to overcome these difficulties. Industry 4.0 and IoT applications, which have been popular in recent years, are the main ones of these methods. With these methods, solutions covering almost every area of our lives started to be produced. This approach, which we also call digitalization, has spread rapidly all over the world. In order for manufacturers to have more advantageous status, they need to reduce production costs in order to achieve more production flexibility and more efficient processes. Digitalization provides great advantages for efficiency increase. This method, which covers the product life cycle in all aspects and provides instant answers, seems to be developed for many years and will remain in the focus of the manufacturers.

Keywords Industry 4.0 · Production enterprises · Internet of things · Industrial automation · Smart factories

Introduction

Industry 4.0 and IoT applications in production enterprises have been one of the most demanded issues in recent years [16]. While rapidly developing digitalization applications produce solutions for almost every area of our lives, the production sector is also affected. The production sector is facing serious competitive conditions within the globalizing world economy [3]. Production companies have to reduce production costs, provide more production flexibility, and more efficient processes in order to become more advantageous than the firms they compete with. The best way to take advantage of competitive advantages is through integrated and innovative electrification, automation, and digitization solutions [15].

F. Ozturk (✉)
Department of Industrial Engineering, Faculty of Engineering and Natural Sciences, Istanbul Medeniyet University, Istanbul, Turkey
e-mail: fatih.ozturk@medeniyet.edu.tr

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We see that Digital Transformation applications, which are developing rapidly all over the world, are now being used in production lines [18]. It is seen that IoT, big data, autonomous robots, simulation, system integration, cybersecurity, and Augmented Reality (AR) applications, which are accepted as the basic components of Industry 4.0, are being preferred for different purposes in different processes in production lines. Digital transformation applications play a very important role, especially in production lines, where there is continuous production. In such production lines, it is one of the demands that the process is required to continue the production continuously [17].

Companies around the world face major challenges due to environmental, social, economic, and technological developments. The most important way to overcome these challenges is to monitor all production processes and have the ability to manage all value chains quickly and responsibly. Companies will need virtual and physical structures that allow close collaboration and rapid adaptation throughout the entire lifecycle, from innovation to production and distribution [12].

Industrial automation systems and digitalization are the most important elements for enterprises aiming to increase efficiency in engineering and operations, reduce operating costs, and improve product quality [23].

By using process control and automation systems, production systems can be managed at a lower cost, process information can be optimized, and energy efficiency can be increased [6]. Digital services play an increasingly important role in decisions such as analyzing or not analyzing process and plant data, applying system components, or simply improving processes.

The fourth industrial revolution, known as Industry 4.0, paves the way for the systematic implementation of a modernized energy network to manage ever-growing energy demand by integrating renewable energy sources [7]. Internet of Things (IoT), industrial internet, cloud-based production [9], and new concepts such as intelligent production partly address these requirements and are often classified by the visionary concept of a fourth industrial revolution.

Industry 4.0 refers to the latest technological advances that the Internet and supporting technologies serve as a backbone that integrates physical objects, human actors, intelligent machines and production lines [27].

By using real-time and high-value support systems, intelligent production has enabled a coordinated, and performance-oriented production initiative that responds quickly to customer demands, minimizes the use of energy and materials, radically improves sustainability, productivity, innovation, and economic competitiveness [32]. Businesses aiming to increase efficiency in engineering and operations, reduce operating costs, and improve product quality want to invest in industrial automation systems and digitalization.

Digitalization Concept and Industry 4.0

In order to talk about Digitalization and Industry 4.0, first of all, it is necessary to make sure that the industrial automation and control systems are fully and accurately designed and operating. Some of the tools used in industrial automation systems can be listed as follows.

PLC (Programmable Logic Controller)

In industrial applications, PLC devices are mostly used as control systems. PLC devices are long-lasting and reliable devices designed for industrial environments. However, hardware prices are high. There is an extra charge for software licenses used to program PLC devices [13].

For each process used in different sectors, the performance requirements of industrial automation and control systems are different. For 'Process Automation' applications, the powerful and reliable PLC controller is of great importance.

Distributed Input and Output Modules (I/O)

Distributed I/O modules have been used in industrial automation and control systems in recent years. Similarly, the use of distributed I/O modules in Process Automation applications has shown a rapid increase. Particularly in 'Process Automation' applications, devices, and sensors within the plant are distributed over a wider area. The electrical connections of the signals from these regions to the I/O modules on the PLC cause both serious labor and high costs. By keeping the PLC control system in the central control room and distributing the I/O modules close to the devices and sensors, it was observed that the electrical wiring to be made was minimized, and the time and cable cost were minimized. Figure 1 shows the deployment of distributed I/O modules in four different locations.

The distributed I/O modules are fully adaptable to the plant structure with a modular, flexible, and integrated structure. It also provides significant savings in many areas such as wiring, assembly, engineering, commissioning, maintenance. The communication protocols of the distributed I/O modules are shown in Table 1 [28].

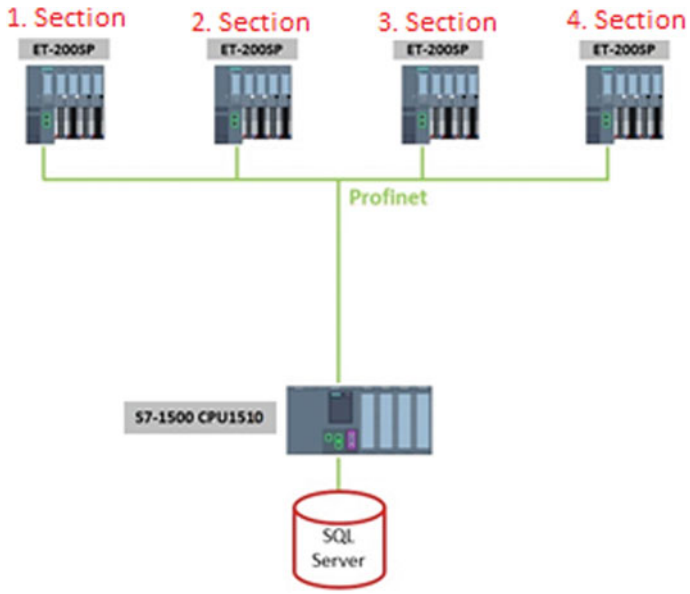

Fig. 1 Application example of distributed I/O modules

Table 1 Distributed I/O modules communication protocols

Pos	Communication protocols
1	PROFINET IO
2	PROFIBUS DP V0/V1
3	IO-Link V1.1
4	AS-Interface
5	Modbus TCP
6	Point to Point (RS 232, RS 485, RS 422)
7	Freeport
8	3964 (R)
9	USS
10	Modbus RTU (master/slave)

HMI (Human Machine Interface)

HMI devices are one of the most used devices after PLC in industrial applications. It is used to monitor process and input information to the PLC program. HMI devices have different sizes and specifications.

Interfaces for audit control in HMI engineering process applications can be regarded as an information integration task. This is especially true for configuration screens, which are the core elements of the high-performance HMI [31].

Industrial Network

Planning, implementing, and linking industrial networks to the enterprise network require a lot of talent and accessible expert knowledge. The same applies when a communication network needs to be secured, diagnosed, or optimized. One of the most important components in Industry 4.0 and digitalization applications is the error-free installation of the industrial network system with the right devices. With the recent use of Industry 4.0 and digitalization applications, there has been an increase in the use of industrial network systems. Thus, the hardware and software costs of industrial network systems used to provide monitoring, control, and diagnostics in industrial systems are reduced. However, there are some application challenges when these new technologies are applied in industrial environments. Given that many of these systems are made up of different distributed systems, management, and coordination are a major challenge [10].

PROFINET (PN) is an industrial Ethernet supported high-level open network communication protocol that uses TCP/P and IT standards in industrial control systems. PN communicates separately with the industrial controllers (PLCs, HMIs, servo drives, RFID (Radio-frequency identification) readers, etc.) scattered throughout the system, ensuring horizontal and vertical integration, ensuring safety, alarm and data transmission faster. According to the timing characteristics, PROFINET defines three types of traffic, as shown in Table 2.

Non Real-Time (NRT) traffic is a typical example of PROFINET CBA networks, real-time (RT) Class 1 can be processed by both PROFINET CBA and IO. RT class 2 performances are only possible with PROFINET IO. Such a class, also known as synchronous, relies on a highly precise and synchronized loop that requires the use of advanced switches capable of predicting delays in which they identify and correct them.

PROFINET IO refers to four types of devices that can be found in the network:

1. IO controller,
2. IO device,
3. IO supervisor,
4. IO parameter server.

    1. The IO controller is "smart" devices, such as personal computers or programmable controllers that perform automation tasks.

Table 2 Profinet timing features [8]

Traffic type	Periodicity/reaction times	Jitter (%)
Non real time (NRT)	$\geq$ 100 ms	$\geq$ 100
Real time class 1	$\geq$ 5 ms	$\geq$ 15
Real time class 2	$\geq$ 250 μs	$\leq$ 0.4 (1 μs)

2. IO devices are devices that perform the interface between IO controllers and field. Examples of these devices include sensors, actuators, valve batteries, electronic terminators, etc.
3. IO supervisors, IO controllers and/or IO devices and devices that change both configuration and diagnostic data.
4. IO parameter servers are devices used to change configuration data for applications with IO devices. Data traffic generated by both IO supervisors and IO parameter servers usually occurs during off-line stages and does not imply real-time performances. Conversely, the exchange of data between IO controllers and IO devices is often related to automation tasks carried out and therefore has critical timing requirements. [8].

After addressing industrial automation and control systems, we can move on to Industry 4.0 and its components.

Industry 4.0

Industry 4.0 is an initiative that combines a range of technologies that help achieve high-throughput production processes. An important feature of industrial production in Industry 4.0 is that physical elements such as sensors, devices, and corporate assets are connected to each other and to the internet. In this environment, devices and sensors generate an increasing amount of data.

An important consideration is that the execution of industrial processes depends not only on the internal situation and user interactions, but also on the context of execution, and provides value-added information to create contextual awareness and improve monitoring [11].

Components of Industry 4.0

When talking about Industry 4.0 and digitalization, it will be useful to give a brief overview of its main components. There are different technologies in the Industry 4.0 concept. These technologies require individual expertise and competence.

Autonomous Robots

One of the first components that come to mind when we say industrial automation is robots or robotic technologies. Robots, which have been used extensively in almost all sectors, have become an important component of Industry 4.0.

Since robots can be applied to all sectors, and their costs are low, industrial robots have been widely used in production areas in recent years [4].

Simulation

Nowadays, while developing technological products, different alternatives are encountered in design studies. It is important to predict how these alternatives affect the performance of the product during the actual application. Computer-aided engineering simulation helps engineers anticipate the effects of a design change by predicting the outcome of any design change on the real-world performance of their products.

Facility design is an important factor affecting the overall performance of production systems. Facility layout design deals with the allocation of machinery/departments in a facility and has a major impact on the efficiency and efficiency of production activities. An effective layout can reduce production costs and improve system performance. Discrete event simulation is an appropriate tool to evaluate the current order, to assess potential alternative areas for improvement by evaluating different settlement alternatives. Therefore, various researchers have applied simulation to different plant layout problems [20]. Simulations will be used more extensively in plant operations to use real-time data to mirror the physical world into a virtual model that can include machines, products, and people, thereby reducing machine setup times and improving quality [26].

Vertical and Horizontal Integration

Vertical and horizontal integration is the integration of all stages of production processes into the system in Industry 4.0 applications. What is essential at Industry 4.0 is that all interconnected systems must constantly communicate with each other and monitor and control each other as necessary.

Two of the most important factors for production in Smart Factories are horizontal and vertical integration. Horizontal integration means creating a network between individual machines, pieces of equipment, or production units, ensuring an uninterrupted flow between each step in the production and planning process, as well as between the steps in the production and planning processes of different enterprises. Vertical integration networks beyond traditional production hierarchy levels mean uninterrupted communication and flow in technological infrastructure. In this context, data obtained from sensors, valves, motors, and enterprise resource planning software and business intelligence applications are handled within this scope.

Internet of Things (IoT)

Businesses who want to increase their production and reduce their production costs need to professionalize their production methods [29]. IIoT (Industrial Internet of Things) can make a definition like this. It is the use of certain IoT technologies in combination with some smart devices in cyber-physical systems in an industrial environment. It can also be expressed as follows, The IIoT vision of the world is a place where interconnected smart things, a larger system or activity as part of the systems that make up intelligent production [5].

With the inclusion of information technologies in production processes, production power can be increased, and processes can be accelerated. With intelligent production processes, intelligent products and remote-control systems can provide a high level of flexibility to production processes. At the same time, it is possible to produce products that can be customized at low costs in line with customer requests by allowing the customers to be integrated into the system.

It is mentioned that the devices make life easier by communicating with the internet of objects, that is, devices communicating with other devices. The data produced by the interaction between the objects enables the industrial processes to be conducted in a more controlled way, to make more detailed analyzes, and to make more dynamic and effective decisions [22]. With this structure, which is also called the Internet of Industrial Objects, factories become smart. Thus, many different and complex structures can be produced in less time and optimum quality. When the devices are connected to each other, the generated data can be transferred rapidly with the support of high-speed internet, and the results obtained from the data obtained can be made faster, and the most effective decisions can be made. These decisions can be transferred to the personnel at work, the manager who follows the work, and all the devices at the same time and can work synchronously. In short, digitalization is not only by transferring the data in the field to digital environments, but also ensuring that these data can be used managerially. Communication systems, which create a vast communication network with the Internet of Things and thus aim to lift the boundary between real and virtual worlds, constitute one of the fundamental forces of Industry 4.0. Industry 4.0-based production processes are based on the fact that systems connect to different networks through different interfaces and communicate with different services. Communication of all devices operating in industrial environments is only possible within a well-designed and configured healthy network. With the developing wired and wireless communication technologies, communication can be made on any platform as well as open-source software and standards developed to provide easier, safer, and manageable communication both in local and wide area networks.

Industrial identification systems are part of industrial communication systems and are one of the main components of Industry 4.0 and IoT systems. Identification systems, also known as RFID (Radio Frequency Identification) systems, digitize organizations with new generation communication technologies and transform them into more efficient and effective systems.

Cyber Security

As a result of the development of information technologies, it became an inseparable part of our lives, digital transformations of our private and public institutions and the targeted and coordinated development of cyber threats caused cyberspace to expand, and cyber threats became a threat to our national security. Today, information and communication technologies (ICT) support most of the industrial production processes. The ICT revolution brought about important transformations in the first and second industrial revolutions, similar to the high effects of mechanics and electricity. This development supported the emergence of cloud-based systems, the Internet of Things (IoT), big data, and the emergence of the Industry 4.0 concept. However, new technological solutions always carry security vulnerabilities that pose unexpected risks [24].

With Industry 4.0 and digitalization applications, cybersecurity has started to pose a major threat to industrial enterprises. The fact that every point in production can communicate with each other in a secure way, the different production facilities can communicate with each other, and the production information is recorded locally or in the cloud makes the data security of production companies important.

Cloud Computing

Cloud computing promises to demand endless and inexpensive resources to provide appropriate infrastructure support for user applications. For this reason, it is increasingly recognized by many businesses that try to move their applications to the cloud to reduce costs and automate reconfiguration. These businesses are supported by free or private cloud platforms that support application deployment and restructuring in the cloud [19].

Cloud security is one of the most important factors preventing cloud usage today. To overcome this reluctance, the cloud application development process must address potential security issues from the outset and adapt to the flexibility offered by the cloud paradigm, as well as the security constraints posed by developers and cloud customers [2].

With the help of Cloud Computing, users can use the applications required for the business in any area over the internet through the computers in the service provider instead of keeping them in on-site computers or data centers. Thus, more economical, flexible, and faster data management can be achieved.

Cyber-Physical Management Systems

Cyber-Physical Systems (CPS) connect the physical world with the virtual computing world with the help of sensors and actuators. CPS's, which are composed of different constituent components, create global behaviors in collaboration. These components often include software systems, communication technologies, sensors/actuators, including embedded technologies, to interact with the real world.

In Smart Factories, production processes mean that devices and systems communicate with each other instantly and identify and regulate all the needs within production processes. For example, if there is a need for material at any stage of production, the required material order is automatically placed, failures can be detected instantly, and on-site and solutions can be offered. Thus, productivity is increased while errors are minimized. CPS are systems that can effectively integrate cyber and physical components using the modern sensor, computing, and networking Technologies [33].

CPS uses data from various sensors for complete information. There is a difference between a malfunction of a sensor during operation and a malfunction of a faulty sensor, and therefore the user can receive incorrect information [30].

Smart production, smart buildings and infrastructures, smart city, smart cars, smart systems and so on. CPS in development is a basic concept [1].

Augmented Reality

Augmented Reality (AR) is a new form of human–machine interaction that encompasses computer-generated information in a real-world environment. The information provided by AR is derived from the actual environment and is, therefore, context-sensitive. The AR can therefore improve the user's appearance with virtual information sensitive to the current state of the surrounding true thickness [25]. With the introduction of the Industry 4.0 concept, AR applications were introduced in digitalized smart factories.

Application examples are used in different scenarios ranging from field service operations to maintenance operations, training, and quality control applications. Within the scope of Industry 4.0, automotive is one of the sectors that benefited the most from AR. AR is used not only in production and maintenance but also in sales. Customers can have driving experience with AR simulation applications if they wish before buying their vehicles. If they wish, they can see the color or accessory options of their favorite vehicles in the AR application.

Big Data and Data Analytics

With the development of technology, devices that communicate with each other, electronic transactions, data traffic, mobile applications, e-mails, videos, pictures, scientific data, etc. The size of the data produced is increasing day by day. In the last few years, especially since 2013, all data sources have increased in terms of the number of records. Trends for scientific publications and funding archives followed a similar path [14]. Keeping such large amounts of data on secure systems and analyzing them and converting them into meaningful information is especially important for production companies.

Particularly in production enterprises, tens of information about production processes can be read and converted into meaningful information, and production can be analyzed, and a serious productivity increase can be achieved.

Result

The transition to a digital transformation to Industry 4.0 naturally has difficulties. In production sectors where technological development and large investments are required, serious costs may initially arise. The promise that manufacturers have an economical size helps them to take the chance of the entire advanced automation and digitization process. Digital transformation and Industry 4.0 bring us convenience in our daily lives and continue to be a part of our lives. It is seen that our quality of life has increased with this transformation, which makes the connections of objects and systems with each other effective and efficient.

In order to show how important and effective the quality management system is, the systematic put forward by Industry 4.0 is important for businesses.

With increasing digitalization, the errors caused by the human factor are reduced, and the system becomes automated, so productivity in production increases, the number of faulty products decreases, and costs are minimized. High efficiency, cost, and minimum errors are a result desired by the quality management system [21]. With Industry 4.0, the adoption of a structure that will ensure the maximum level of customer satisfaction in production and service encourages digitalization for businesses.

References

1. Alguliyev R, Imamverdiyev Y, Sukhostat L (2018) Cyber-physical systems and their security issues. Comput Ind 100:212–223
2. Casola V, De Benedictis A, Rak M, Rios E (2016) Security-by-design in clouds: a security-SLA driven methodology to build secure cloud applications. CLOUD FORWARD: from distributed to complete computing. Proc Comput Sci 97:18–20

3. Celik N, Ozturk F (2017) The Upcoming issues of industry 4.0 on occupational health and safety specialized on turkey example. Int J Econ Bus Manage Res 1(5):236–256
4. Chen Y, Dong F (2013) Robot machining: recent development and future research issues. Int J Adv Prod Technol 66:1489–1497
5. Conway J 2015 The industrial internet of things: an evolution to a smart production enterprise. Schneider Electric Whitepaper, pp 2
6. Edgar TF, Pistikopoulos EN (2018) Smart production and energy systems. Comput Chem Eng 114:130–144
7. Faheem M, Shah SBH, Butt RA, Raza B, Anwar M, Ashraf MW, Ngadi MdA, Gungor VC (2018) Smart grid communication and information technologies in the perspective of Industry 4.0: Opportunities and challenges. Comput Sci Rev 30:1–30
8. Ferrari P, Flammini A, Vitturi S (2006) Performance analysis of PROFINET networks. Comput Stand Interf 28(4):369–385
9. Gao R, Wang L, Teti R, Dornfeld D, Kumara S, Mori M, Helu M (2015) Cloud-enabled prognosis for production. CIRP Ann-Prod Technol 64(2):749–772
10. Gholami M, Taboun MS, Brennan RW (2017) A wireless intelligent network for industrial control. 27th Int Conf Flexible Autom Intell Prod 11:878–888
11. Giustozzi F, Saunier J, Zanni-Merk C (2018) Context modeling for industry 4.0: an ontology-based proposal. Proc Comput Sci 126:675–684
12. Gligor DM, Holcom MC (2012) Understanding the role of logistics capabilities in achieving supply chain agility: a systematic literature review. Surg Endosc Other Interv Tech 17(4):438–453
13. Hoxha V, Bula I, Shala M, Hajrizi E (2016) Cost-oriented open source automation potential application in industrial control applications. IFAC-PapersOnLine 49(29):212–214
14. Huang Y, Porter AL, Cunningham SW, Robinson DKR, Liu J, Zhu D (2018) A technology delivery system for characterizing the supply side of technology emergence: Illustrated for big data and analytics. Technol Forecast Soc Chang 130:165–176
15. Kayar A, Ayvaz B, Öztürk F (2018) Akıllı Fabrikalar, Akıllı Üretim: Endüstri 4.0'a Genel Bakış". In: International Eurasian conference on science, engineering and technology (EurasianSciEnTech 2018), Nov 22–23, Ankara, Turkey, pp 1661–1668
16. Kayar A, Ozturk F (2019) Predictive maintenance in Industry 4.0 applications. Int Conf Life and Eng Sci ICOLES 27(29):16
17. Kayar A, Ozturk F (2019) Machine data collection and analysis in industry 4.0 applications. Int Conf Life Eng Sci ICOLES 27(29):317–322
18. Kayar A, Ozturk F, Kayacan O (2019) Fast fault solving methods in smart manufacturing lines with augmented reality applications. Recent Adv Data Sci Bus Anal 25(28):182–187
19. Kritikos K, Massonet P (2016) An integrated meta-model for cloud application security modelling, CLOUD FORWARD: from distributed to complete computing. CF, Madrid, Spain, pp 18–20
20. Negahban A, Smith JS (2014) Simulation for production system design and operation: literature review and analysis. J Prod Syst 33:241–261
21. Ozturk F (2014) Qualität, Effizienzsteigerung und integrierte Managementsystemen im türkischen Eisenbahnsektor. Soc Nat Sci J 8(2):14–19
22. Ozturk F, Kayar A (2019) Product lifecycle management in smart factories: industry 4.0 applications. In: Proceedings of 10th international symposium on intelligent manufacturing and service systems. Istanbul/Turkey, pp 1420–1427
23. Ozturk F, Kayar A, Vatansever A (2019) Advanced manufacturing with industry 4.0 applications. In: 5th international conference on advances in mechanicalengineering. Istanbul/Turkey, pp 17–19
24. Pereira T, Barreto L, Amaral A (2017) Network and information security challenges within Industry 4.0 paradigm. In: Production engineering society international conference. Vigo (Pontevedra), Spain, pp 28–30
25. Reinhart G, Patron C (2003) Integrating augmented reality in the assembly domain—fundamentals benefits and applications. CIRP Ann 52(1):5–8

26. Rüßmann M, Lorenz M, Gerbert P, Waldner M (2015) Industry 4.0: the future of productivity and growth in production industries, 09 Apr 2015, pp 1–14
27. Schumacher A, Erol S, Sihn W (2016) A maturity model for assessing Industry 4.0 readiness and maturity of production enterprises. Proc CIRP 52:161–166
28. Siemens Industry Mall Web Site (2019) https://w3.siemens.com/mcms/distributed-io/en/ip20-systems/et-200sp/et200sp-communication-modules/pages/default.aspx
29. Singh D, Tripathi G, Jara AJ (2014) A survey of internet-of-things: future vision, architecture, challenges and services. In: IEEE world forum on internet of things 2014. Seoul, pp 287–292
30. Tang L-A, Yu X, Kim S, Gu Q, Han J, Leung A, La Porta T (2013) Trustworthiness analysis of sensor data in cyber-physical systems. J Comput Syst Sci 79:383–401
31. Urbas L, Obst M, Stöss M (2012) Formal models for high performance HMI engineering. IFAC Proc 45(2):854–859
32. Yuan Z, Qin W, Zhao J (2017) Smart production for the oil refining and petrochemical industry. Engineering 3(2):179–182
33. Zeadally S, Jabeur N (2016) Cyber-physical system design with sensor networking technologies. The Institution of Engineering and Technology, London UK