Chapter 1
Introduction

1.1 IoT Overview

The Internet of things (IoT) [1–3] can be formulated as a system of mutually related objects, computing devices, machines, animals, or people, which are equipped with unique identifiers and the possibility of transferring data over a network without the necessity of human-to-human or human-to-computer interactions. Thus, an IoT system consists of connected assets, which can communicate and share information.

The IoT enables assets to observe and interact with the surrounding environment, i.e., they can hear, see, "think" and perform the required actions while sharing information and coordinating decisions. As a result, the IoT transforms the form of these assets from traditional into a smart one. Such a transformation is realized with several important technologies related but not limited to computing, embedded devices, sensor networks, communication strategies as well as Internet protocols. Figure 1.1 illustrates a general IoT structure. The development of the IoT field is persistently stimulated by its application in several domains like the following:

- logistics and transportation [4–6],
- industrial [7–9, 9, 10],
- smart buildings [11],
- agriculture and environment [12–14],
- hospitality and leisure [15, 16],
- healthcare [17].

The objective of the subsequent sections is to briefly review application of the IoT in selected areas. In particular, the review should be perceived as a radar of the main trends rather than a complete state-of-the art analysis.

1.1.1 Logistics and Transportation

The section aims at providing a review of selected works concerning logistics and transportation application. The concept of smart logistics [6] and the related tech-

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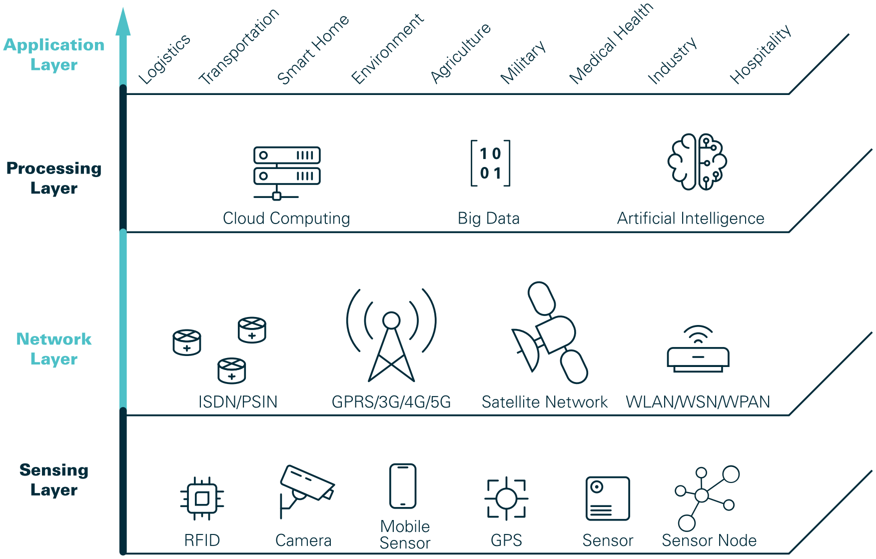

Fig. 1.1 General IoT architecture

nology can be clearly visualized using Fig. 1.2. As in other areas, the number of IoT applications is proliferating constantly. This can be clearly seen in the recent survey papers [4–6]. Nevertheless, there are general application areas, which can be split into the following categories:

- logistics and manufacturing optimization [18–24],
- vehicle status monitoring [25–27],
- cargo status monitoring [28, 29],
- driver monitoring [30–32],
- smart warehousing [33–36].

Thus, the objective of the remaining part of this section is to provide a concise overview of the content of those papers. In particular, in [18], the authors show how to integrate a cloud manufacturing infrastructure with the IoT. As a result, a multi-level dynamic adaptation of a smart logistic synchronization control is attained. The problem of optimizing manufacturing time and energy consumption within a reasonable computing time is proposed in [19]. Such an effect is achieved with an IoT infrastructure coupled with self-organizing configuration mechanisms as well as the related data-driven models. An intelligent IoT-based dispatching platform is proposed in [20]. It couples the IoT with a multi-objective optimization model and a two-level optimization algorithm, which uses the celebrated Dijkstra strategy along with an ant colony approach. A method integrating the blockchain with the IoT is proposed in [21]. The paper shows two real-life examples, which tackle the design and deployment of a logistic and transportation system. In [22], a logistic service supply chain coupled with an IoT-based logistic/service, information and fund flow

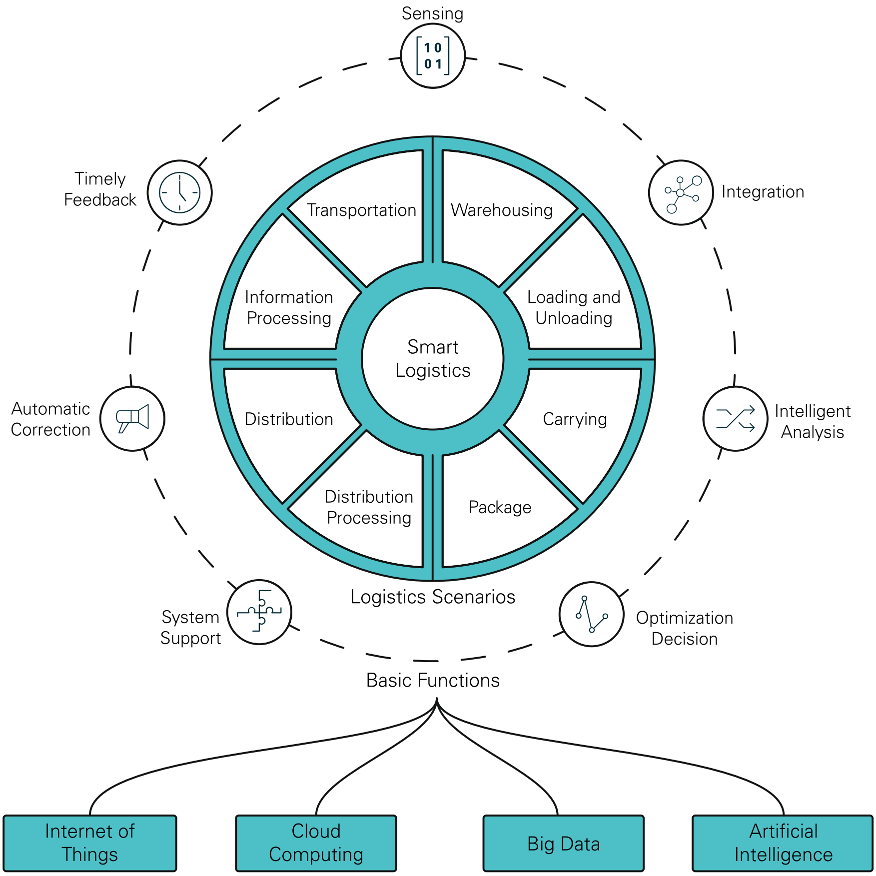

Fig. 1.2 Smart logistics components

is analysed. A decomposition strategy of a complex distribution network is presented in [23]. This is attained by splitting it into smaller nodes, communicating via the IoT. In particular, the IoT forms the basis for a digital twin of the real system, which enables its efficient functioning. An IoT-based real-time sensing model of logistic resources is proposed in [24]. It enables dynamic task distribution within a logistic system.

Several interesting strategies are also proposed in the context of vehicle tracking and monitoring. Indeed, the IoT equipped with a combination of GPS and GSM/GPRS technologies is used to transmit vehicle coordinates and store them in a designated database [25]. The IoT is also employed to vehicle traffic congestion monitoring and control [26]. This strategy allows providing the status and density of the traffic, both of which are transmitted using the Bluetooth technology. Apart from vehicle tracking, a cargo monitoring system is proposed in [28], where cargo tracking is realized with real-time data gathering and suitable information processing. Another IoT-based intelligent cargo tracking system is presented in [27]. It overcomes the unappealing effect of losing GPS signals in environments like dense urban areas and underground tunnels. In particular, a combination of radio-frequency identification and a global system for mobile communication is efficiently used to overcome the difficulties with GPS. In [29], an intelligent cargo solution is proposed, which adapts the IoT to spread information processing between mobile and distributed devices. As a result, they are communicating with themselves as well as with a dedicated platform. The services provided by this platform include cargo localization, rerouting and condition monitoring without human intervention.

Another important aspect pertaining to the performance and safety of logistic and transportation systems is human factors. Indeed, it is very important to monitor driver behaviour in real-time. For that purpose, the work [30] proposes a fusion of the IoT and fog computing. In this architecture, all of the driver's influential, environmental, and vehicle factors are analysed using multiple sensors. In [31], a connected car architecture along with an IoT architecture is used for designing a model for driver behaviour analysis. The strategy is implemented with embedded devices, smartphones as well as a dedicated cloud service. A driver style assessment system is presented in [32]. It uses a dedicated IoT to assess of the driving style using vehicle measurements like speed, acceleration, jerking, engine rotational speed as well as driving time.

The last group of logistic and transportation systems concerns warehouse management as well as related forklift performance. In [33], the authors propose an IoT-based warehouse management system with advanced data analysis and computational intelligence. The system aims at increasing productivity and picking accuracy, efficiency as well as robustness to order variability. The work [34] proposes an IoT infrastructure which combines location information with warehouse working procedures. The system uses a proactive tracking architecture employing the iBeacon tag technology and the concept of distributed gateways. There are also several works dealing with forklifts, e.g., [35, 36]. In the first one [35], a forklift is equipped with an RFID transceiver, a pallet cage as well as electromagnetic field measurement. These can then be used for various analytical deliberations. The second work [36] tackles the problem of improving forklift dispatching and reducing a costs associated with the delays of loading/unloading delivery trucks. For that purpose, forklifts are equipped with sensor nodes that enable collecting such data as the forklifts' physical location, usage time, bumping/collision history, and the battery status. Finally, the information acquired is combined with inventory information and fed into a sophisticated stochastic learning system, which generates dispatching recommendations.

1.1.2 Industrial Applications

As in the case of logistics and transportation, the number of industrial IoT application is also proliferating constantly. This can be clearly seen in the recent survey papers

[7–10, 37]. Generally, industrial applications can be split into the following categories:

- users and system monitoring [38–42],
- programmable logic controllers (PLCs) [43, 44],
- supervisory control and data acquisition (SCADA) [45–49],
- mobile robots [50, 51],
- cyber-physical systems [51–53].

These application areas are rather evident as it is obvious that in any kind of industry one can easily find PLCs and SCADA systems. Thus, in [43], a device called an IoT-PLC is proposed, which can be perceived as a PLC tailored for Industry 4.0. The crucial feature of this device include: regulatory control capabilities, fog-computing functionalities such as filtering and field data storage, and multiple wireless interfaces managed independently. It also uses digital twins of real devices, and hence it can transparently interact with the upper cloud level. As the IIoT can be be implemented for critical infrastructures, while attacks on them may cause significant disruptions. In [54], the authors developed a PLC and IoT-based indoor power line communication system. Subsequently, the work [44] investigates an approach for efficient transmission of data between the PLC and cloud platforms.

As SCADA systems are commonly used to control IIoT, the authors of [45] investigate the results of attacking them and provide some general guidelines for security improvement. In [47], a SCADA system which is based on an open source Thinger platform is proposed. It incorporates IoT-oriented web services with the conventional SCADA. The IoT infrastructure includes several sensors, e.g., current and voltage ones, which are used for control purposes. In [48], the authors investigate security and privacy of SCADA-based IoT critical infrastructures. In particular, a dedicate toolbox is proposed, which can tackle the above issues in an efficient way. The toolbox incorporates such functionalities as cryptography-based access to cloud services using identity-based cryptography and signature schemes at the fog layer. A SCADA system which integrates the IoT technology for real-time water quality monitoring is proposed in [49]. The developed system can determine the contamination of water, leakage in pipelines, and some crucial water parameters, e.g., temperature, flow, color, etc. Subsequently, an IoT platform for real-time production performance analysis and exception diagnosis is proposed in [55]. As a result, a decision tree is used for diagnosing exceptions and providing concise information about them.

Another industrial application concerns the development of widely understood cyber-physical systems. In particular, in [56], the authors proposed a platform and software architecture describing features like semantic device interoperability and entity virtualization. This IoT-oriented strategy allows locating and selecting available resources and devices. A wireless senor network-based process automation monitoring architecture is proposed in [41]. In the approach, the monitoring information is shared in accordance with widely used management standards. In [52], a cyber-physical system which makes it possible to virtualize manufacturing resources is proposed. In the work [57], the authors present an IoT architecture which translates unique identifiers of physical objects to concrete network addresses. As a result, information about an object, e.g. its status, location, etc., can be extracted. An IoT architecture based on the OPC.NET specification which can be employed for both industrial applications and smart buildings is proposed in [58]. A cyber-physical architecture for the Industry 4.0-based power equipment detection system is proposed in [51]. It integrates many kinds of technologies, including virtual instrumentation, detection and measurement, mechanical and electrical devices, network communication and mobile clients. As a result, the cyber-physical system provides coordination among networks and physical layers. This should be realized by a suitable symbiosis of computation, communications and control (3C) technologies. The resulting 3C framework can perform real-time sensing, control and diagnosis of complex industrial systems [59].

Finally, an IoT system capable of localizing mobile robots is proposed in [50]. It employs neural networks (see, e.g., [60, 61]) for image processing purposes. The resulting mechanism uses the topological mapping method to gain orientation in the explored environment.

1.1.3 Agriculture and Environmental Applications

The number of agriculture-oriented applications is also constantly increasing, and hence their optimization with respect to various factors, e.g., water consumption or soil quality, is of paramount importance. Apart from agriculture, we are currently witnessing a significant development of green energy sources. In both, these fields, the IoT technologies [12–14] play crucial roles in fostering their further development. Indeed, the development areas can be roughly characterized of:

- energy management [62, 63],
- air monitoring [64, 65],
- soil monitoring [66],
- water monitoring [67, 68],
- plant monitoring [69],
- solar panels [62, 70],
- wind turbines [71–73].

In [74], the authors proposed solar tracking system, which eliminates the unappealing shading effect of nearby solar panels, which is encountered in instant positioning of solar panels. They tackle this problem through the use of an IoT-based solution deployed in solar panels, which increases solar energy harvesting efficiency. The work [62] proposes a new energy management strategy for solar-powered devices that intend to power the load directly from the solar cell. This strategy avoids converting and storing the energy, which eliminates losses. Concerning wind turbines, the work [71] uses the IoT for monitoring their behaviour. The authors of [72] analyse recent trends in the application of the IoT in energy generation, specifically in relation to wind energy generation. They investigate potential uses of the IoT pertaining to its integration with energy generation systems, monitoring and control, as well as maintenance and prediction. The interesting work [73] proposes an 8×8 (64) IoT-based wind farm platform which is built using miniaturized wind turbines with wireless connectivity. Such an IoT grid can measure wind speed and wind direction, which is necessary for optimal wind farm management. The work highlights the potential of using an inexpensive wireless, battery-powered IoT rather than a data-logger that has limited data storage and cannot be accessed remotely.

Concerning agricultural applications, an intelligent approach for efficient plant irrigation is proposed in [70]. It utilizes the IoT and a set of sensors for recording plants data as well as their watering requirements. The system is implemented with a mobile phone, and hence it allows continuous monitoring and control of irrigation efficiency. The work [63] proposes a framework for green mobile crowd sensing. The approach is designed in such a way that only a selected set of best performing sensors is used, which allows significant energy savings. An IoT-based real-time microclimate monitoring system is proposed in [64]. The system includes temperature and relative humidity sensors, powered by solar panels. An environmental monitoring system for apple orchards is presented in [65]. Subsequently, a framework for monitoring multi-layer soil temperature and moisture is proposed in [66]. The framework consists of monitoring nodes, a gateway node and a system platform. The authors of [67] propose an IoT solution for water quality assessment through the measurement of conductivity, temperature, and turbidity. In [68], an IoT infrastructure is presented which consists of sensor nodes providing hydrographic information. Finally, an IoT-based water irrigation scheduling platform is proposed in [69]. In particular, the authors develop a decision support system for irrigation scheduling of olive fields.

1.1.4 Hospitality and Leisure Industry Applications

Since the hospitality and leisure industry plays an important role in our lives, the IoT technology also contributes actively to their permanent development [15, 16]. The main trends can be summarized as follows (cf. Fig. 1.3):

- automatic check-in [75, 76],
- guest experience [16, 77, 78],
- cashless payment systems [79],
- security, privacy and ethical issues [80].

The paper [75] proposes a location recognition algorithm for automatic check-in applications. It can be implemented with smartphones and integrated with a designated cloud platform. The system uses GPS and WiFi access points, which results in a new strategy called a WiFi fingerprint. In [76], the authors propose a malicious check-in defense scheme. They also use the concept of the WiFi fingerprint and make it secure against in unpermitted access. Another improvement of the scheme proposed in [75] is given [81]. The contribution enhances the existing strategy and

Fig. 1.3 Trends in the hospitality and leisure industry

eliminates the need for using GPS. Another automatic vehicle check-in check-out strategy is proposed in [82]. It eliminates the manual entry process and minimizes the security personal effort by exploiting the image data of the vehicle number plate. The work [77] highlights the application of a wristband (Disney's MagicBand) that serves in Disney World as a credit card, FastPass, hotel key, etc. The authors investigate the IoT impact on enhancing guest experience as well as to better understands guest behaviour and needs. Another IoT cashless payment system for the hospitality industry is proposed in [79]. Subsequently, in [78], the authors explore the influence of demographic factors (education, gender, age, etc.) on consumer attitudes and intentions for using IoT in the hospitality industry. The work [83] proposes an IoT architecture for the hospitality industry located in the so-called smart cities. Finally, an IoT-based authentication system for a remote opening and closing door lock is presented in [84].

1.1.5 Healthcare

Similarly as in the hospitality and leisure industry, the number of IoT applications in healthcare is proliferating [17]. Generally, the applications can be split into two groups:

- health parameters [85, 86],
- patient behaviour [87–90].

In particular, the work [85] proposes a new signal quality-aware IoT electrocardiogram telemetry system for continuous cardiac health monitoring. Similarly, IoT electrocardiogram telemetry is used in [91, 92] analysis and classification pertaining to heartbeat diagnosis. An IoT-based e-health monitoring system is proposed in [93]. An appealing property of this approach is that it aims at controlling temperature raising caused by an on-body sensor, which affects skin comfort. An IoT system monitoring cardiac arrhythmia is presented in [86]. Moreover, an IoT-based heart rate monitoring system is proposed in [94].

Concerning patient behaviour, the authors of [87] propose an IoT device in the form of wearable smart glasses, which are able to monitor eye blinks. In [88], a healthcare digital twin of a patient is presented which utilizes the IoT technologies and AI models to diagnose the state of health and provide a set of clinical questions leading to the final diagnosis. The authors of [89] employ a foot movement monitoring strategy for detecting an early stage of the Alzheimer disease. Finally, the work [90] proposes an IoT system which aims at enhancing speech-language capabilities of patients with Parkinson's disease.

1.2 Where Does KIS.ME Go?

Permanent cost pressure rises the need for a continuous optimization of internal processes, and hence, improve their overall effectiveness and performance. To attain such a challenging objective, the underlying processes have to be measurable and transparent. This means that irrespective of the considered application area, a set of suitable measures has to be introduced. Generally, the real-time and automatic recording and displaying of parameters related to quality, performance and availability are of paramount importance. Indeed, they enable optimization in manufacturing processes and automatic calculation of OEE (overall equipment effectiveness) indicators. Another common approach is to employ SPC (statistical process control), which makes it possible to get a predictable behaviour of the manufacturing system and keep its crucial parameters under the constrained control limits. Irrespective of the approach being used, the resulting data can be used, e.g., to measure and analyse downtimes, bottlenecks, and other causes of inappropriate performance. As a result, a dedicated implementation of the process optimization and efficiency improvements can applied.

There is no doubt that digitalization solutions from Industry 4.0 and the Internet of Things (IoT) can be perceived as excellent candidate strategies capable of handling the above stated issues concerning measurements and transparency. Such solutions should be applicable for both humans and the machines. Even more, they should integrate them to make their cooperation as efficient as possible.

Therefore, instead of deliberating about hypothetical IoT onboarding platforms capable of handling the above stated challenges, an existing and efficient one is employed within the framework of this book. The onboarding platform is called

Fig. 1.4 KIS.ME: Communicate, develop, deploy, control

KIS.ME and the remaining part of this section answers all crucial questions pertaining to its practical advanced applications.

KIS.ME (Keep It Simple.Manage Everything) is an IoT platform which was designed under the light of the following sentence:

Digitization made easy:
It can be this easy to optimize your process and increase efficiency.

The justification of this sentence can be split into four crucial components (Fig. 1.4):

- communicate,
- develop,
- deploy,
- control.

Let us start by stating fundamental questions concerning communication:

1. How to communicate with human operators?
2. How to communicate with machines?

To answer these, it is assumed that the processes considered are discrete- event ones [95, 96]. To make the discussion clearer, let us provide the definition of the system state, which is a set of variables that can be used to describe the system's past and future behaviour. Thus, the discrete event system is a discrete-state, event-driven one. This means that its state can only take discrete values from a possibly infinite set. Moreover, its state evolution depends solely on the occurrence of discrete events over time. In the IoT framework, events can be generated using both IoT devices and the cloud platform connected with them. Under these preliminaries, one can quickly figure out that buttons and lights are the most common communication tools used by human operators. Contrarily, machines can be communicated through various inputs and outputs located at their inlets and outlets, respectively. Thus, by finding a common denominator between humans and machines, KIS.ME offers three devices:

KIS.BOX: a two-button box with digital inputs/outputs,
KIS.LIGHT: a signal lamp with digital inputs/outputs.
KIS.IO: an input/output communication box.

These KIS.Devices are communicated through WiFi and should be perceived as a universal hardware inherently integrated with the cloud application called KIS.MANAGER. Note that both devices can communicate discrete states through both digital inputs/outputs or by illuminating colors with the buttons and a lamp.

Let us proceed to crucial questions pertaining to the development stage:

1. How to digitize existing or new processes in a possibly fast and effective way?
2. How to manage and interfere state transitions?
3. How to asses system behaviour and visualize its performance?
4. How to asses system effectiveness and performance predictability?

The answer to the first question is associated with preparing a KIS.Device installation scheme, i.e., it should be located in such a way as to provide appropriate transition of the discrete state. This can be realized through colored lights or digital inputs/outputs of KIS.Devices. The second question is answered by the functionalities of KIS.MANAGER. In particular, it can process the data gathered from KIS.Devices and interact with them through the so-called Rule engine, which should be perceived as a rule base shaping system behaviour. As for third question, it is necessary to explain that the data from KIS.Devices is represented in KIS.MANAGER with the so-called Datapoint. Each numerical or logical Datapoints can be visualized, processed or analysed within a given period. As a result, key performance indicators (KPIs) can be intuitively formulated using a predefined list of commands. Moreover, system transparency can be settled with digital twins of KIS.Devices that can be obtained in KIS.MANAGER. Additionally, digital twins can be located within the floorplan, which is a virtual counterpart of the real system structure. To answer the last question, appropriate KPIs and performance cost functions can be defined. They can be used for the calculation of overall equipment efficiency (OEE) as well as to form control charts to be used for observing and analysing system predictability. Indeed, these control charts form the basis for statistical process control (SPC), which is a commonly used tool for assessing system performance and predictability.

Usually the deployment stage can be a bottleneck on the way towards better performing systems. Indeed, it frequently requires integration of hardware and software provided by different manufacturers. As a result, a third party integrator is usually needed, to make it possible to complete the deployment stage. KIS.ME provides an integrated hardware/software platform, and hence the deployment stage is significantly simplified and does not require extraordinary efforts or costs. In other words, an optimally performed development stage yields smooth realization of the deployment one.

The control stage addresses the following questions:

1. What is process availability?
2. What is process performance?
3. What is process quality?
4. Is the process in the statistical control state?
5. What are (if any) special cause process variations?

KIS.ME provides all necessary and sufficient tools for assessing individual or combined processes' availability. This can be achieved with KPIs calculating an exact run time of the associated equipment. Subsequently, it can be compared with the planned time. Similarly, knowing an ideal process cycle time, a KPI can be implemented calculating the total number of process cycles. Finally, by multiplying it by the ideal process cycle time and then comparing the result with the run time one can obtain process performance. Process quality can be measured in a binary way or with multi-valued quality levels. In both cases KIS.ME can provide a suitable set of KPIs capable of assessing process quality in an intuitive and efficient way.

To answer the last question we should clarify when the process in the statistical control state. Namely, the process is in the state of control if it is subject to common cause variations only, which can be expected in any set of observations. These common cause variations are predictable and limited, e.g., the discrepancy between consecutive battery mounting times. Indeed, it varies in time but it is possible to assess the range of its variability. Contrarily, special cause variations can be associated with unexpected and unappealing factors that impair process realization, e.g., an equipment fault, quality issues, human operator-related issues, etc. As a result, it is said that the process is in the out-of-control state if it is subject to both common and special cause variations. Thus, apart from the inevitable random and typical fluctuations, other unappealing factors affect process parameters. All these factors can be communicated to KIS.MANGER using KIS.Devices.

Although KIS.ME was originally intended for logistic and industrial applications, it can be applied to settle various tasks encountered in Industry 4.0 and beyond. Thus, the objective of the subsequent part of this book is to introduce the reader into the arcane details of KIS.ME.

1.3 Contents of the Book

The reminder of the book is divided into six chapters and two appendices. However, the book can be generally divided into two parts. The first one introduces the KIS.ME platform as a modern IoT onboarding one. The second one discusses theoretical and practical aspects of applying such a platform for a wide spectrum of advanced applications ranging from logistics and SPC to advanced process and transportation scheduling algorithms. In particular, Chap. 2 introduces the reader into the KIS.ME IoT platform and its hierarchical overview. It discusses also an intuitive concept of Datapoints, which constitute the main source of knowledge about the current status of an asset. It is also shown how to place assets inside workspaces and associate with them a set of functional rules using Rule engine. In Chap. 3, a set of practical guidelines for implementing various logistics-oriented applications is presented. This part starts with a crucial issue pertaining to access control using KIS.Devices and external RFID readers. The remaining three sections deal with transportation systems as well as their digitization and visualization. Subsequently, Chap. 4 aims at introducing the concepts of calculated Datapoints and key performance indicators, which form the basis of statistical process control. Having such tools, a set of widget charts is introduced, which enable data visualization and analysis. Subsequently, practical examples concerning the development of statistical control charts are presented. Chapter 5 aims at exploiting the methods and tools described in the preceding parts to develop a set of selected process monitoring and control schemes. In particular, it starts with the transportation system, which operates on a set of selected routes. To measure the performance of such a system, a suitable cost function is introduced, which can be monitored and controlled by the designated supervisor. Subsequently, quality control strategies are proposed and described in detail. The last process monitoring strategy aims at calculating and visualizing overall equipment efficiency, which is widely perceived as a key measurement tool for assessing both productivity and efficiency. The objective of Chap. 6 is to provide a list of selected potential applications of KIS.ME. They stem from scientific deliberations of the authors and can be perceived as prospective proofs-of-concept, which can be deployed in various industries. The chapter starts with modelling users and their interactions, which include various important components, e.g., experience and performance. The resulting models make it possible to schedule the work of human operators in a reasonable and predictable way. The chapter discusses also the issues of health-aware and fault-tolerant control and shows a general solution which can overcome these important problems. Subsequently, the objective of Chap. 7 is to provide a concise overview of KIS.API, which can be used for an effective communication with external applications.

All chapters are summarized with a set of exercises motivating the reader to obtain further skills pertaining to practical applications of the modern IoT.

Finally, Appendix A provides a list of KIS.ME commands along with their sample applications. Similarly, Appendix B surveys KIS.ME Datapoints along with their example applications.

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