Quality Control in the Context of Industry 4.0

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1 Introduction

Industry 4.0 is an industry concept that recently appeared that encompasses the main technological innovations in the fields of automation, control, and information technology applied to manufacturing processes. It includes concepts beginning from Cyber-Physical Systems, Internet of Things (IoT) and Internet Services, production processes tend to become increasingly efficient, autonomous, and customizable [1].

This means a new period in the context of the great industrial revolutions, naming this the fourth revolution. With smart factories, a number of changes will take place in the way the products will be manufactured, impacting several market sectors [2].

The quality control could highly benefit from this paradigm shift on account of the gradually significant spread of sensor technology on shop floors, where the quality engineers will be able to gather as much measurement data as possible, opening the possibility to detect defects that otherwise would be undetected. This paradigm shift could also open the doors to the possibility to record 100% of measured data, therefore, signifying that the recorded data for the quality control no longer will need certain statistical tools since a 100% control could be a reality. This change is rather fundamental since every single defective piece could be identified and thus segregated [3].

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Sensors could be integrated into machines since measuring capabilities could be added to every machine tool. However, many challenges arise from this possibility, such as significant costs due to the sensor integration and interferences from the manufacturing process such as humidity, dust, and temperature. The machine tool must then be capable to obtain much more data with the assistance of WSNs in very short periods of time. This means that the current sensors must be substituted by WSNs, since a connected infrastructure is a vital requirement to utilize the possibilities of instantaneous measurements with the highest efficiency [4].

Engineers and decision-makers will require a clear and interactive evaluation of the data. The fusion of data must be possible in order for this to function and it should be obtained from distinct sensors thus leading to a combined result from different measurements. With the purpose of coping with the intricate networks of a certain process, data mining algorithms such adaptive neuro-fuzzy inference system or neural networks could be used to achieve the combined result from different measurements [5].

2 Industry 4.0

The term Industry 4.0 originated from a project of the German government that aimed to stimulate new technological strategies [6]. The drastic paradigm shift currently occurring in industrial activity requires strong assimilation of digital communication systems with the industrial process. This means a new period in the context of an industrial revolution. With intelligent factories, a number of changes will take place in the way the products will be manufactured which has the potential to impact several markets. Thus, with this blend, the aim is to reinvent services, products, and methods of production. It can be perceived as a technological revolution defined by the merger of a physical domain—the industrial units and the virtual domain—digital communication systems. This integration could lead to a universal integration of information, products, processes, machines, sites, and people [7, 8].

The concept of Industry 4.0 foments the connectivity between physical objects such as machines and devices, sensors, and company's assets, and to the cloud [6]. This allows the stakeholders to access any required information in real time. The rapid evolution witnessed in image and pattern recognition and sensor technologies allow for innovative forms of solutions [9]. As can be observed in Fig. 1, adapted from [10], a wide range of technologies and elements that are integral to Industry 4.0 are represented. Some of these elements are the cyber-physical systems (CPS), Internet of Things (IoT), Smart Factory and Big Data.

The crucial aim of the Industry 4.0 concept is to further fulfill the customer requirements, thus affecting the most distinct areas of manufacturing, beginning with the research and development (R&D), management, commissioning, logistics up to the use of products and recycling [11]. It is worth mentioning that an important advantage of Industry 4.0 in detriment of Computer Integrated Manufacturing (CIM)

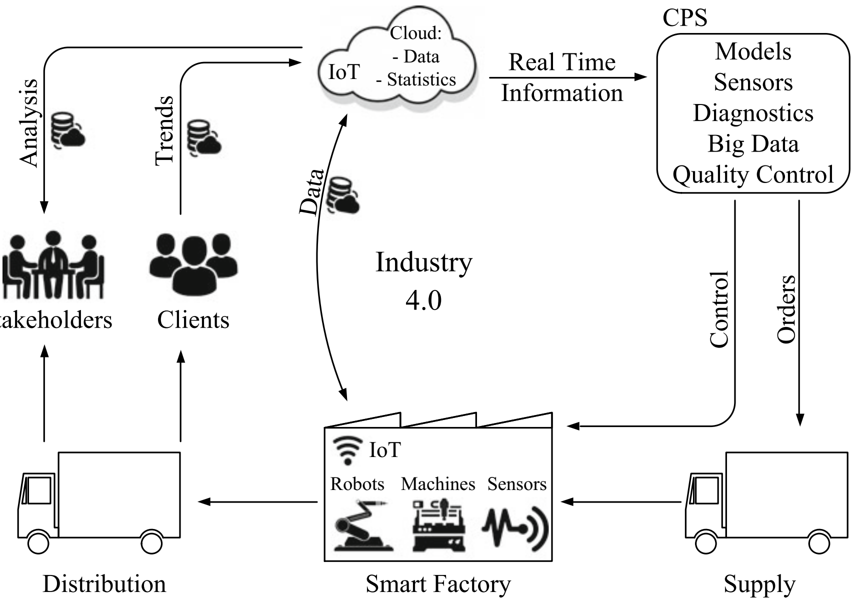

Fig. 1 A figure illustrating the main elements of Industry 4.0

is the regard for the human role in the entire production process since, in the case of CIM, the employees influence in manufacturing is limited [12].

2.1 The Cyber-Physical Systems (CPS)

The cyber-physical systems (CPS) are a concept of the merger between the physical and digital worlds with the analytic instruments, aiming to improve the industry's efficiency [10]. The CPS's broad adoption is closely related to Industry 4.0. Strategic technological concepts part of the CPS comprise trends such as cloud computing, Internet of Things (IoT), smart technologies and Big Data. The CPS is the foundation of the several new technological areas: smart medicine, smart manufacturing, smart city, smart buildings, smart electric vehicles, mobile systems, wearable devices, novel defense systems, among others [13].

2.2 Smart Factory

It is somewhat hard to pinpoint the exact definition of the smart factory. According to [14] a *Smart Factory* is defined as a manufacturing solution that conveys an adaptive and flexible manufacture process which has the potential to overcome arising challenges within a fast-changing reality with growing complexity. Such type of a unique solution may well be related to an increasing automation, perceived as a merger of hardware, software, and/or mechanics, leading to optimization at the industrial unit. This solution could cause a decrease in needless labor and a reduction of waste. In contrast, it may well be perceived in a viewpoint of a partnership among distinct industrial and nonindustrial partners, in which the "*Smart*" element contributes to establishing a dynamic organization [14].

2.3 Big Data

In the last decade, massive volumes of data are generated daily at unparalleled levels and with distinct origins. Thus, it is necessary to process, read and efficiently manage enormous data sets [15]. Big Data is a term that defines the vast quantity of data that is generated and processed by systems with a strong processing capacity. The distributed applications support these types of multiple connection systems [16]. What distinguishes such types of data is the lack of capability to analyze it by employing common database, processing, and management tools [17]. The implementation of Big Data could affect several fields of application such as entertainment, financial, healthcare, communication, security, agriculture, and, naturally, manufacturing [18]. The concept of Big Data generates opportunities for the industry to generate products with a higher added-value [19]. The idea is to obtain added value from the variety and quantity of data by being capable to analyze and process it in real time.

2.4 Internet of Things

IoT has many definitions, one of them is given in [20] in which is proposed to merge entirely user-centered and technical definitions by describing IoT as a network of networks. This network could, through wireless mobile devices and unified/standardized electronic identification systems, identify unequivocally physical objects and digital entities. This will allow the user to be capable of recovering, storing, transferring and processing, and always keeping the connection between the virtual and physical worlds [21]. However, if defined by a more practical perspective, the IoT entails the standardized and direct digital identification of a physical object (for instance, with SMTP protocols, IP address, http, among others) through the use of a wireless network [22].

3 The Importance of Quality Control

The formal definition of quality defined by ISO 9001 is: "Degree in which a set of inherent characteristics satisfies the requirements" [23]. In other words, ensuring the quality of a product or service is to ensure that its values are satisfactorily met by the final costumer. To ensure the overall quality—processes, products, machinery, equipment, and systems must meet the statutory and contractual quality requirements. A quality management system includes all the activities of the global management that determine the quality policy, objectives, and responsibilities, as well as their implementation. As ISO 9000 explains, a management system provides the means to establish a policy and objectives and the means to achieve them [24].

Quality, independent of the branch in which it operates, should not be viewed by organizations as a mere monitoring tool, but rather as a mechanism to anticipate problems, preventing them from occurring, and, ultimately, if they occur, solving them. Faced with an ever-changing reality full of new developments, new products, brands and competitors, the tools provided by a robust quality control system reinforce the structure of the key strategies for maintaining and strengthening the link with the final customer. Consequently, among the several advantages of quality control, there is an increase in sales and competitiveness, image consolidation, customer loyalty, among others. Overall, a well-implemented quality management system improves the organization, providing a competitive advantage [25].

The production systems are becoming increasingly flexible due to a higher customer heterogeneity, an overall more demanding customer, fiercer competition, and faster-evolving technology [26]. The tendency of the production is to be made in small batches, the quantity of pieces per batch is reduced, the variety is high, the product size is unequal, the tool change and setup is constant [27], the level of precision is distinct. Therefore, it becomes challenging to utilize classical tools such as the statistical process control (SPC) in order to create control charts with the aim of overseeing the overall production process [28]. Thus, many challenges arise regarding the quality control under the uncertainty of and the rapid evolution of the industrial sector and Industry 4.0 could be a potential solution.

4 The Link Between Quality Control and Industry 4.0

Industry 4.0 covers a wide range of technologies that allow the progress of the value chain and through this concept will be possible to diminish manufacturing lead times and to improve the quality of the overall organizational performance and the final product [29]. The combined structures of data could enable the capacity to locate any specific product and/or equipment or any associated information [30]. The estimated value of the combined structures of data for the industrial sector is, as stated by Gifford et al. [31], to convey operating efficiency through a tighter control, in real time, of the equipment, energy, quality, and reliability.

The main purpose is the possible profits of a given organization by reducing the total costs of the produced piece [32]. In order to achieve such a goal, and to comply with ever-growing demands of the client, it is necessary to increase the flexibility of the production systems [33]. The consequence of such a production model is the production in small batch sizes in shorter periods of time and with an increased complexity. Decentralizing the structures of the production is an additional aim of employing Industry 4.0 and is a way to reduce the complexity [29]. Since a high level of productivity has to be achieved to stay competitive and in order to provide more and more customized products, which is a competitive advantage, Industry 4.0 centers on the improvement of the competitiveness through cost reduction and flexibility increase in a decentralized production system [32]. However, quality suffers when customized products are manufactured in small batch sizes since it is increasingly challenging to utilize common methods to control quality [34] and to inspect the production process when the production is made in small batches [28]. This means that it is more likely to obtain flawed assessments and give false alarms due to a lack of sample data and erroneous measurements. This is why it is particularly important to integrate and apply the tools of Industry 4.0 to the quality control in order to decidedly increase the precision of the measurements.

With the aim of researching this impact as well as the utilized methods, a comprehensive analysis of the effect of Industry 4.0 on quality control is imperative. The integration of WSNs and IoT is a substantial challenge and it should be implemented to guide engineers to make the correct decisions. As a consequence, by utilizing machine learning and smart sensors, irregularities could be automatically accommodated by the process in order to guarantee the best possible quality of the final product [35]. As it can be assessed from Fig. 1, the quality control could play an important role in Industry 4.0 and several advantages can be gained from this paradigm shift on account of the increasingly significant dissemination of sensor technologies on shop floors, where the quality engineers will be allowed to harvest as much measurement data as possible, thus opening the possibility to detect defects that otherwise would be dispatched undetected. This paradigm shift could also open the doors to the possibility to document 100% of the measured data. As a result, this means that the recorded data for the quality control no longer will need certain statistical tools since a 100% quality control in real time could be a reality. This change is rather fundamental since every single defective piece could be instantly identified and thus segregated [3].

However, improving the precision of the piece measurements in order to boost the quality of the finished product might not be the only contribution of Industry 4.0 to the overall quality. The tools of Industry 4.0 could contribute to increase the quality in other stages of the entire process of production, such as the quality of information required for optimization, planning, and operation, the quality of forecasting, simulations and prototyping and could even the contribute to a better worker participation and engagement.

4.1 The Quality of Information

The strength of the connection of the digital, the service, and the physical domains will ultimately define the quality of information necessary for planning, operation, and optimization of the process [36]. The reason is that when data is transmitted in real-time the transparency and the quality of the information increases [35]. By acquiring and processing, the information of the product [37] with high quality and precision will allow automatic monitoring and awareness which will result in a growth in efficiency of all the elements of Industry 4.0 concept [38]. The production process and the quality management system will gather and utilize such types of novel information/data for a finer and more precise decision-making and processes evaluation. Such strength will improve the modern quality management, since it not only tries to prevent the production and delivery of defected products but also tries to guarantee the highest possible performance with the best possible efficiency for every process of an enterprise [3].

4.2 Improving the Quality of the Forecast

A few of Industry 4.0 tools could support the improvement of the production leveling (*heijunka*). For example, the quality of the forecast could be improved by data analytics. The planning becomes easier if data history is utilized at the same time as the data related to a superior understanding of the customer's requirements by making a detailed market analysis [29]. Here, Big Data can be utilized for a thorough analysis of data recorded beforehand and utilized to detect problems which might occur in distinct production processes and could also be used to forecast the occurrence of future problems. Big Data could also be used to find several solutions that could prevent the aforementioned problems of occurring once more [39].

4.3 Simulations and Prototyping

Simulations and prototyping could allow the use of real-time data to emulate the physical production process in a computer-generated model. The model could comprise products, machines, and operators. This will allow testing and optimizing the machine characteristics, in the simulation, for the succeeding product previous to any real-life fabrication, therefore, reducing setup times and increasing the overall quality [29]. By employing simulations of a production process will not only help diminish the downtimes and setup times but it will also help to decrease the number of production failures in the start-up phase [40]. The quality of the decision-making could also be enhanced if simulations are used for this purpose. Products could also be constantly improved by using simulations. This signifies that when a product is developed, its production could be simulated at the same time, which would allow to identify obstacles and quality problems and create the possibility to eliminate them before the first piece is ever produced [41].

4.4 Worker Participation and Engagement

The topic of the participation of operators in the production processes is another element of Industry 4.0. This is a paradigm with connections to digital culture, digital society, and Industry 4.0 [7]. When human labor in the context of Industry 4.0 and smart factory is addressed, these terms are frequently recurring: passion, flexibility, responsibility, participation, integration motivation, and teamwork [7]. The participating routines of the operators largely depend on the tool change utilized in the workshop and on the habits that stem from such tools [7]. The desired type of the future factory operator is to be proactive and participative, contrasting with a reactive or resistant type of operator. In the Industry 4.0 concept, the emphasis of the enterprise should be the operator participation and the integration of the worker into the decision-making process, similar to the digital networks [7].

5 Current Challenges

Several challenges still persist for the implementation of Industry 4.0 and specifically, the blending of quality control with this new paradigm. Some of the challenges concerning quality are listed as follows:

- Lack of processing capacity—The fast spread of IoT has cemented the basis of Industry 4.0 by digitally connecting objects and devices. However, such types of changes create also challenges concerning several factors. For instance, some of the challenges are the effective management of the huge quantities of data, the process of such types of data, their storage, and their conversion into useful information and thus improving the decision-making [42].
- Absence of feedback for the required information on quality—According to a study made in [43] in the vehicle assembly industry, the feedback concerning data on quality as fed to quality engineers and systems is only found to a limited degree. The real-time feeding of dada was also lacking and is communicated with a time delay. The feedback on quality to different areas of the process occurred only in dispersed intervals of time and only in situations of a worrying quality irregularity or defect, usually in which the ones where the identification feedback took several working hours [43].
- The absence of a connection between the system and the operator in the quality context is another negative challenge that needs to be overcome. A "*smart*" method needs to be put in place for the quality control concerning the link between system

and human. In this case, what is necessary is ample, real-time feedback of data concerning quality with a user-friendly visualization of the condition of the quality [30].

- Complete information preparation for a proper visualization—The state of the quality needs to be properly visualized by the operator or the engineer. In the study made in made in [43], the way the quality information was visualized was restricted to only a few elementary important data. In order to overcome this challenge the applied technologies should be more complete and crafted in a user-friendly manner in order to properly visualize the state of the quality [43].
- A poor application of technologies oriented for the process—The workspace technologies such as the visual information that assists the operator might not be correctly integrated into the production process which could also occur with the process control and quality feedback. The physical machines and devices need to be correctly connected to the implemented quality systems [43].

6 Conclusion

Industry 4.0 is a concept that is already a reality and begins to have an effect on the operational indicators of enterprises. At the basis of this revolution are the WSN since they consist of spatially dispersed and independent sensors capable to monitor physical or environmental characteristics. Products, machines, and people will be connected, increasingly in number through WSN and IoT. With these tools in smart factories, a number of changes will take place in the way the products will be manufactured, impacting several market sectors. The measurement for the quality control no longer will be made in a distinct metrology section, but instantaneously on the production line. The WSN will open the door to register and transmit the collected data for quality control thus opening a full range of possibilities in this field.

In this paper, a broad analysis of the link between quality control and Industry 4.0 was made. Several benefits and challenges are addressed. Besides the direct improvement of the quality control, the set of tools of Industry 4.0 could strengthen the quality in all stages of the entire process of production, such as the quality of information required for optimization, planning and operation, the quality of forecasting, simulations and prototyping and could even the lead to a better employee participation and engagement.

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References

1. Lasi, H., Fettke, P., Kemper, H.-G., Feld, T., Hoffmann, M.: Industry 4.0. Bus. Inf. Syst. Eng. **6**, 239–242 (2014)
2. Salkin, C., Oner, M., Ustundag, A., Cevikcan, E.: A conceptual framework for Industry 4.0. In: Industry 4.0: Managing The Digital Transformation. pp. 3–23. Springer, Cham (2018)
3. Foidl, H., Felderer, M.: Research challenges of Industry 4.0 for quality management. In: Innovations in Enterprise Information Systems Management and Engineering. pp. 121–137. Springer, Cham (2015)
4. Chen, B., Wan, J., Shu, L., Li, P., Mukherjee, M., Yin, B.: Smart factory of Industry 4.0: key technologies, application case, and challenges. IEEE Access. **6**, 6505–6519 (2018)
5. Ahuett-Garza, H., Kurfess, T.: A brief discussion on the trends of habilitating technologies for Industry 4.0 and smart manufacturing. Manuf. Lett. (2018)
6. Müller, J.M., Buliga, O., Voigt, K.-I.: Fortune favors the prepared: how SMEs approach business model innovations in Industry 4.0. Technol. Forecast. Soc. Change. **132**, 2–17 (2018)
7. Mazali, T.: From industry 4.0 to society 4.0, there and back. AI Soc. 1–7 (2017)
8. Pedone, G., Mezgár, I.: Model similarity evidence and interoperability affinity in cloud-ready Industry 4.0 technologies. Comput. Ind. **100**, 278–286 (2018)
9. Fuchs, A.: Industrial Trucks in the Age of Industry 4.0. ATZoffhighway Worldw. **9**, 3–3 (2016)
10. Ahuett-Garza, H., Kurfess, T.: A brief discussion on the trends of habilitating technologies for Industry 4.0 and smart manufacturing. Manuf. Lett. **15**, 60–63 (2018)
11. Reischauer, G.: Industry 4.0 as policy-driven discourse to institutionalize innovation systems in manufacturing. Technol. Forecast. Soc. Change. **132**, 26–33 (2018)
12. Featherstone, S.: 13—Computer-integrated manufacturing. In: Featherstone, S. (ed.) A Complete Course in Canning and Related Processes (Fourteenth Edition). pp. 269–275. Woodhead Publishing (2015)
13. Alguliyev, R., Imamverdiyev, Y., Sukhostat, L.: Cyber-physical systems and their security issues. Comput. Ind. **100**, 212–223 (2018)
14. Radziwon, A., Bilberg, A., Bogers, M., Madsen, E.S.: The smart factory: exploring adaptive and flexible manufacturing solutions. Procedia Eng. **69**, 1184–1190 (2014)
15. . Oussous, A., Benjelloun, F.-Z., Ait Lahcen, A., Belfkih, S.: Big Data technologies: A survey. J. King Saud Univ. Comput. Inf. Sci. (2017
16. Chen, M., Mao, S., Zhang, Y., Leung, V.C.M.: Introduction. In: Big Data. pp. 1–10. Springer, Cham (2014)
17. Anshari, M., Almunawar, M.N., Lim, S.A., Al-Mudimigh, A.: Customer relationship management and big data enabled: personalization and customization of services. Appl. Comput. Inform. (2018)
18. Caesarius, L.M., Hohenthal, J.: Searching for big data: how incumbents explore a possible adoption of big data technologies. Scand. J. Manag. **34**, 129–140 (2018)
19. Nimmagadda, S.L., Reiners, T., Wood, L.C.: On big data-guided upstream business research and its knowledge management. J. Bus. Res. **89**, 143–158 (2018)
20. Benghozi, P.-J., Bureau, S., Massit-Folléa, F.: Définir l'internet des objets. In: L'Internet des objets : Quels enjeux pour l'Europe. pp. 15–23. Éditions de la Maison des sciences de l'homme, Paris (2012)
21. Lanotte, R., Merro, M.: A semantic theory of the internet of things. Inf. Comput. **259**, 72–101 (2018)
22. Kouicem, D.E., Bouabdallah, A., Lakhlef, H.: Internet of things security: a top-down survey. Comput. Netw. **141**, 199–221 (2018)
23. Standardization, I.O.: for: ISO 9001:2015, Fifth Edition: Quality management systems—Requirements. Multiple, Distributed through American National Standards Institute (2015)
24. Manders, B., de Vries, H.J., Blind, K.: ISO 9001 and product innovation: a literature review and research framework. Technovation. **48–49**, 41–55 (2016)
25. Natarajan, D.: ISO 9001 Quality management systems. Springer International Publishing (2017)

26. Van den Broeke, M.M., Boute, R.N., Van Mieghem, J.A.: Platform flexibility strategies: R&D investment versus production customization tradeoff. Eur. J. Oper. Res. **270**, 475–486 (2018)
27. Denkena, B., Krüger, M., Schmidt, J.: Condition-based tool management for small batch production. Int. J. Adv. Manuf. Technol. **74**, 471–480 (2014)
28. Liu, C., Wang, H., Fu, X., Xie, D.: Research on Quality Control under Small Batch Production Condition. In: 2010 International Conference on Measuring Technology and Mechatronics Automation. pp. 147–150 (2010)
29. Kamble, S.S., Gunasekaran, A., Gawankar, S.A.: Sustainable Industry 4.0 framework: a systematic literature review identifying the current trends and future perspectives. Process Saf. Environ. Prot. **117**, 408–425 (2018)
30. Telukdarie, A., Buhulaiga, E.A., Bag, S., Gupta, S., Luo, Z.: Industry 4.0 implementation for multinationals. Process Saf. Environ. Prot. (2018)
31. Gifford, C.: The MOM Chronicles ISA-95 Best Practice Book 3.0. International Society of Automation, Research Triangle Park, NC (2013)
32. Meissner, H., Ilsen, R., Aurich, J.C.: Analysis of control architectures in the context of Industry 4.0. Procedia CIRP. **62**, 165–169 (2017)
33. Godina, R., Matias, J.C.O.: Improvement of the statistical process control through an enhanced test of normality. In: 2018 7th International Conference on Industrial Technology and Management (ICITM). pp. 17–21 (2018)
34. Li, P., Jiang, P.: Research on quality-oriented outsourcing decision architecture for small-batch parts of multistage machining processes. In: Proceedings of the 22nd International Conference on Industrial Engineering and Engineering Management 2015. pp. 427–433. Atlantis Press, Paris (2016)
35. Mayr, A., Weigelt, M., Kühl, A., Grimm, S., Erll, A., Potzel, M., Franke, J.: Lean 4.0-A conceptual conjunction of lean management and Industry 4.0. Procedia CIRP. **72**, 622–628 (2018)
36. Vaidya, S., Ambad, P., Bhosle, S.: Industry 4.0—a glimpse. Procedia Manuf. 20, 233–238 (2018)
37. Merino, J., Caballero, I., Rivas, B., Serrano, M., Piattini, M.: A data quality in use model for Big Data. Future Gener. Comput. Syst. **63**, 123–130 (2016)
38. Sung, T.K.: Industry 4.0: A Korea perspective. Technol. Forecast. Soc. Change. **132**, 40–45 (2018)
39. Bagheri, B., Yang, S., Kao, H.-A., Lee, J.: Cyber-physical systems architecture for self-aware machines in Industry 4.0 Environment. IFAC-Pap. **48**, 1622–1627 (2015)
40. Simons, S., Abé, P., Neser, S.: Learning in the AutFab—The Fully Automated Industrie 4.0 Learning factory of the University of Applied Sciences Darmstadt. Procedia Manuf. **9**, 81–88 (2017)
41. Schuh, G., Potente, T., Wesch-Potente, C., Weber, A.R., Prote, J.-P.: Collaboration Mechanisms to Increase Productivity in the Context of Industrie 4.0. Procedia CIRP. **19**, 51–56 (2014)
42. Sittón, I., Rodríguez, S.: Pattern extraction for the design of predictive models in Industry 4.0. In: Trends in Cyber-Physical Multi-Agent Systems. The PAAMS Collection—15th International Conference, PAAMS 2017. pp. 258–261. Springer, Cham (2017)
43. Gewohn, M., Beyerer, J., Usländer, T., Sutschet, G.: A quality visualization model for the evaluation and control of quality in vehicle assembly. In: 2018 7th International Conference on Industrial Technology and Management (ICITM). pp. 1–10 (2018)