
DIGITAL FACTORY IN THE UNIVERSITY OF PANNONIA NAGYKANIZSA CAMPUS — THE FACTORY SUBSYSTEM

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ABSTRACT

One of the new challenges of the 21st century is the Industry 4.0. Manufacturing companies moving away from mass production and getting closer to customized production and manufacturing of customized products through digitization. The expectations are high, meeting the requirements is a real challenge to industrial partners. In order to help meet the challenges the University of Pannonia Nagykanizsa Campus started to establish a fully automatized industrial laboratory. In this paper the architecture of the Industry 4.0 laboratory and the purpose of the Factory Subsystem is presented.

Keywords: Industry 4.0; digital factory; innovation, communication

1. INTRODUCTION

Digitization, the deployment of information technology and automation have great impact in manufacturing industry and manufacturing companies. The operation of manufacturing companies has changed significantly, it is switched from mass production to customized products and production. Industry 4.0 strategy includes several key technologies to digitize production flow or even the whole supply chain. The University of Pannonia Nagykanizsa Campus is establishing an Industry 4.0 laboratory. The goal of the laboratory is to cover most areas of factory digitalization.

Not only the production but the entire supply chain, i.e. from acquisition to customer services, will be modelled in the laboratory. It requires the integration of different research areas and technologies e.g. adaptive systems, data mining, machine learning, optimization, protocol technology, sensor and computer networks. These key technologies may provide to model the main elements of the fully automated industrial processes that leads to efficiency gains and allows to produce highly customized product at small lot size.

In this paper the structure of the laboratory is presented and the role and functions of its Factory Subsystem is described in details. The paper is organized as follows. Section 2 describes Industry 4.0 and learning factory concepts. In Section 3 problem statement is presented. Section 4 presents the system plan of the laboratory. Section 5 introduces the Factory Subsystem. The last section concludes the paper.

2. INDUSTRY 4.0 AND LEARNING FACTORIES

Nowadays we are facing of the next industrial revolution, so-called Industry 4.0. The term Industry 4.0 has been introduced by the German government. The complexity of manufacturing systems and the need of customized products yield to the digitalization of the production. The digitalization cannot be realized effectively without computerization. The continuous evolution of information technology like Cyber-Physical Systems (CPS), Internet of Things (IoT), Internet of Services (IoS), robotics, cloud- and cognitive computing, big data and augmented reality (AR) results significant change in production systems [1] [2].

The concept of the Industry 4.0 digitalizes the whole supply chain to be able to make fully customized products [3]. This approach is used worldwide but some countries use different terms. For example, in the USA it is called “reindustrialization” of the manufacturing industry, in Japan “New Robot Strategy” for producing cooperative robots, in China “Made-in-China 2025”, in France “New Industrial France”, in UK “high-value manufacturing” and in South Korea “advanced innovators’ strategy” [4] [5] [6] [7] [8].

The Industry 4.0 is a widely researched area, systematic literature reviews are frequently published [5] [9] [10] [11]. Most research papers in this area are mainly focused on the technological aspects [12] [13] [14] but the human operators also are important part of the production systems [15] [16] [17] [18] [19]. The newest development of IoT devices has the possibility to design machines which can replace human minds [20].

Numerous papers exist about learning factories focusing on Industry 4.0. These factories have different look and purpose and they demonstrate different implementation aspects [21] [22] [23] [24] [25]. There are reviews demonstrating the existing approaches of learning factories available in academia and industry [26] [27] [28] [29].

3. PROBLEM STATEMENT

The technology is developing continuously by humanity. Many important breakthroughs were seen in the past. But none of them was as important as that is now in progress. It has many names around the world as Industry 4.0, IIoT, Digital Factory. The essence is not the name, but the available technologies and their possible interconnections.

Naturally, this process has advantages and disadvantage too and now we can hardly see what will happen exactly in the near future. But what we clearly see is the following. The complexity and the capability of these systems stand on incredible level. The knowledge that needs to create, update or operate these kinds of solution is also high. The fact is, the humanity has a big chance with this to do something really good. Probably, this will bring fundamental changes in all areas of our lives. But we can only use this opportunity if we can prepare ourselves in time.

Our goal is to create a multipurpose laboratory in the area of Industry 4.0. This solution will be able to use in the followings:

- The laboratory will serve as an infrastructural basis for useful industrial researches, which in the future can contribute to the development of the Industry 4.0 concept and its newer versions.
- The infrastructure of the laboratory will support the teaching of modern industrial processes. The students can learn about the structure and the interoperation of this modular architecture, i.e. students can learn the functions, working flows and the place of the main units / components / elements / entities of the modern digital industrial area.
- The students can understand the whole system and the relationship between each unit.
- The motivation and innovation level of the students are kept high and give them a chance to develop new capabilities of the system.
- It can become a cooperation and collaboration environment between the university and the industrial partners. The laboratory can demonstrate the possibilities of this new technology in practice. Moreover, this environment makes it possible on the one hand to introduce and on the other hand to develop and test new technologies before industrial deployment.

An important design aspect is to develop the laboratory with modular structure. This property is important in many cases. One of these is that the capabilities of the laboratory can be expanded or modified with the help of minor improvements. On the other hand, we can schedule of the activation time of some functions of the system. This enables this development on a campus with small resource.

4. SYSTEM PLAN

Our system will include all main components of a modern, fully automated industrial solution. This is necessary to reach the multipurpose operational area. Note that we want to model this process from the ordering of a customized product - through the production - to the customer's service, i.e. the whole supply chain. This activity requires coordinated work of numerous research areas.

There are some dominant areas for example adaptive systems, data mining, machine learning, optimization, protocol technology, and sensor and computer networks.

Fig. 1 shows the logical structure of the system, where the tasks of each element are the followings:

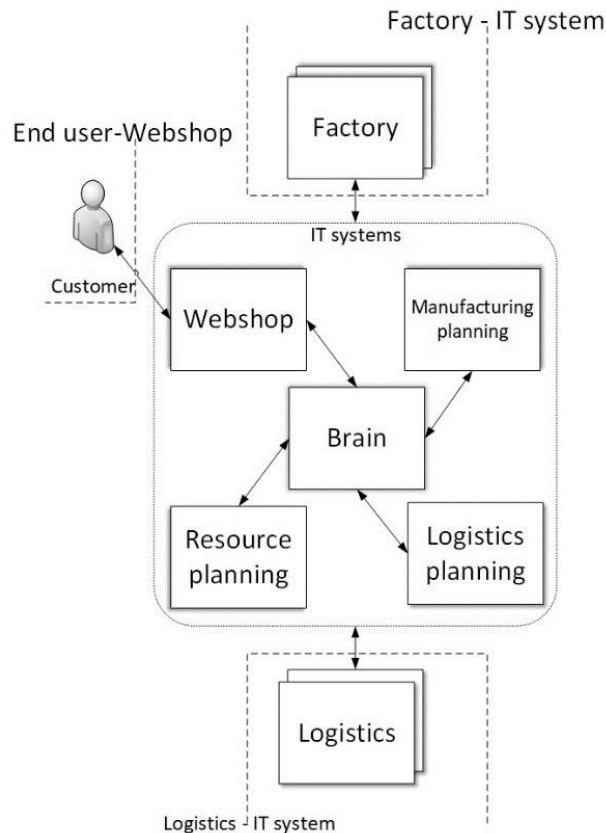


Figure 1. The logical structure of the system

Customer: This entity indicates the manufacturing process. Note that this means the factory will only produce the ordered products.

Brain: This is the central unit and its main functions are the process control and the information management: collection and transmission of information.

Webshop: The customer can manage (buy, modify, get information) his/her order with the help of this unit. This subsystem communicates with the brain unit.

Manufacturing planning: This unit determines the production scheduling and the raw material requirements based on the order.

Logistics planning: This unit determines the scheduling of logistics for the manufacturing process based on the order.

Resource planning: This unit selects the specific factory and logistics partner involved in the manufacturing process based on the availability information and manufacturing parameters.

Logistics: This unit is responsible for transportation, it provides information on its activities.

Factory: The task of this unit is the physical production. It provides information on its activities.

It is important to note that the Webshop, the Brain, the Manufacturing planning, the Logistics planning and the Resource Planning are IT systems / services that work together in the process.

Because of its complexity, the system will be implemented in several phases. Therefore, the individual functions will be integrated step by step into the system. In the first phase the Factory Subsystem will be realized. The next section describes the architecture of the Factory Subsystem in details.

5. FACTORY SUBSYSTEM

The task of the Factory Subsystem is to start and coordinate the manufacturing processes necessary to fulfill the orders. There are many aspects to consider when planning the manufacturing processes. This becomes more difficult, when we want to expand the manufacturing processes with further processes, taking into account the currently running ones. This requires centralized manufacturing planning that should guide all sub-components.

Fig. 2 shows the logical structure of the Factory Subsystem. The main information is provided by the Enterprise Resource Planning System (ERPS). It is transmitted through an interface that forms a transition between a particular ERPS and the specific control software. The purpose of the interface is to connect different ERPSs and modular control systems.

The Manufacturing Controller (MC) can deliver tasks in the form of instructions from the data contained in the ERPSs (orders, manufacturing scheme, etc.). The MC includes the Manufacturing Logistics Controller, which controls material handling between the factory and the factory-owned warehouse. It also includes the Manufacturing Line Controller (MLC) that controls the robot or machine controllers performing operations during production. The MLC includes a Manufacturing Line Logistics Controller that controls the material delivery between the robots/machines or production lines required for a given production process, and also includes Host Controllers.

A Host Controller contains the control programs of an associated machine or robot. The Host Controllers communicate with the device using an interface, give instructions and receive feedback about the status of the operations. Depending on their type, this information is returned to the Host Controller or the Data Collector Internal Controller. The purpose of the latter is to further analyse and subsequently optimize operations based on the data obtained during operations, both locally and at a high level.

5.1 Factory Information Flow

The MC is responsible for scheduling and assigning existing and ongoing production processes from the newly received order (received from the ERPS) between the MLCs. It is also tasked with giving instructions to the MLC on which Manufacturing Line needs to meet the order in which they are to be delivered, and where to place the existing goods (intermediate or finished product) from the Manufacturing Line (warehouse or to other Manufacturing Line). The MC can schedule further processes from the returned data and return the status of the running processes to the ERPS and indicate the completion of orders.

The task of the Manufacturing Logistics Controller is to define and pass on the instructions for moving materials within the warehouse to the controllers of the logistics tools. Starting from the current inventory of the factory-owned warehouse (which is constantly updated), it can coordinate all material handling processes. A further task is to supply the production line of the associated Factory and to coordinate the supply according to the instructions of the MC. The MLC controls the controllers of the devices that perform operations within the Factory and schedule the associated devices. On the basis of the instructions received from the production control, the instruction sequences are issued to the Host Controllers in the order specified. An instruction contains the product manufacturing sub-scheme that the device must perform and the repeat number of the operation. The Manufacturing Line Logistics Controller receives the instructions that meet the needs of the raw material needed to perform the given Host operation, as well as the material delivery tasks between the Hosts.

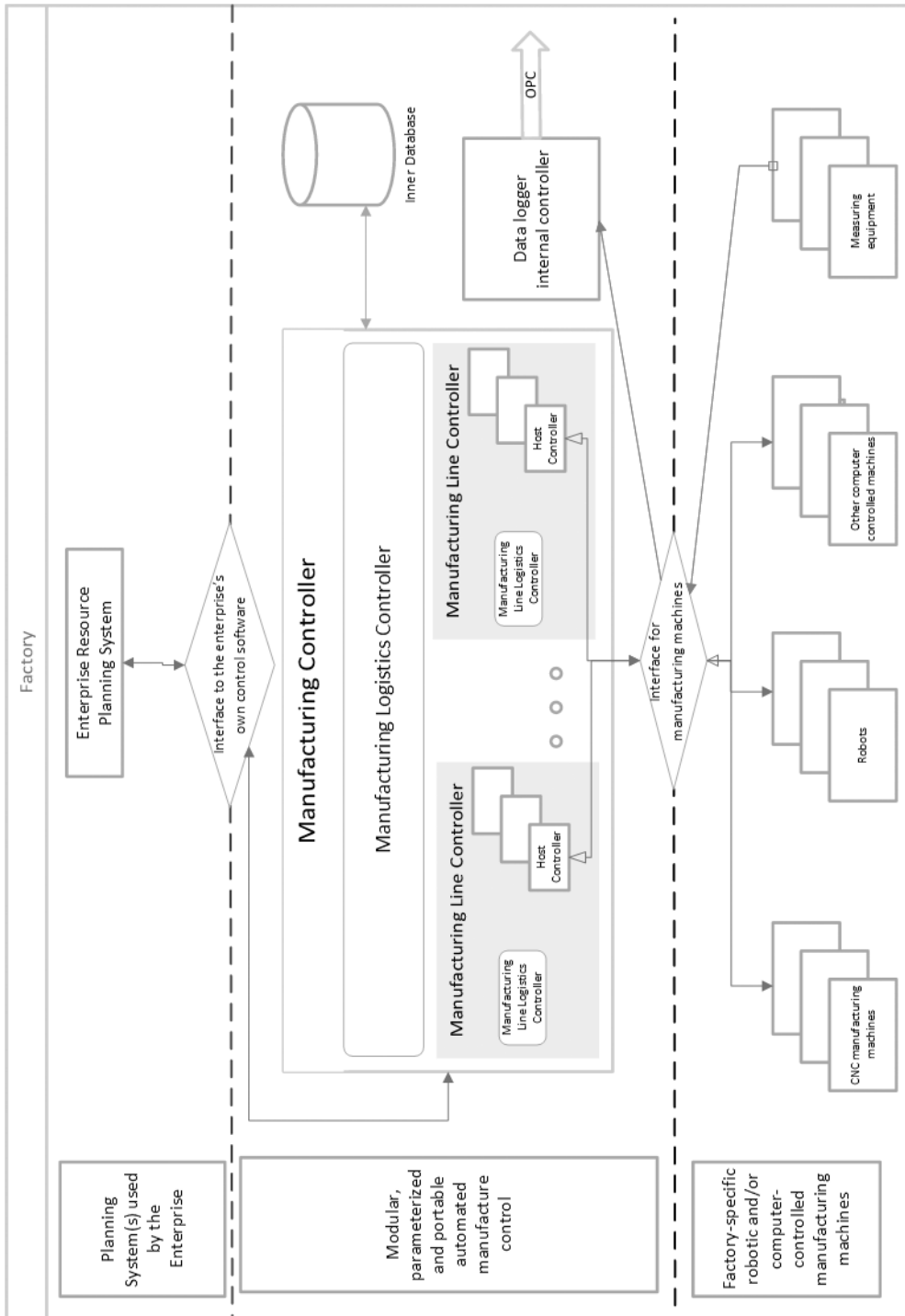


Figure 2. The Factory Subsystem

6. CONCLUSION

Industry 4.0 strategy includes a number of modern technologies that can be used to digitize production or even the entire supply chain. In University of Pannonia Nagykanizsa Campus an Industry 4.0 based laboratory is currently under construction. The aims of the laboratory are teaching university students, making research in the field of Industry 4.0 and implementing industrial flows in small scale.

The present paper is represented the modular model of the laboratory especially the Factory Subsystem. Currently, the model is being implemented. During the first phase of the realization the Factory Subsystem is developed. The task of this unit is the physical production. The paper presents the logical structure and the information flow of the subsystem.

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REFERENCES

- [1] R. Schmidt, M. Möhring, R.C. Härtig, C. Reichstein, P. Neumaier, P. Jozinović, Industry 4.0-potentials for creating smart products: Empirical research results, In International Conference on Business Information Systems, Springer: Cham, Germany, 12, 2015, pp. 16–27.
- [2] A. Pereira, F. Romero, A review of the meanings and the implications of the Industry 4.0 concept, *Procedia Manuf.*, 13, 2017, pp. 1206–1214.
- [3] S. Ford, M. Despeisse, Additive manufacturing and sustainability: An exploratory study of the advantages and challenges, *J. Clean. Prod.*, 137, 2016, pp. 1573–1587.
- [4] S. Wang, J. Wan, D. Zhang, D. Li, C. Zhang, Towards smart factory for industry 4.0: A self-organized multi-agent system with big data based feedback and coordination, *Comput. Netw.*, 101, 2016, pp. 158–168.
- [5] L.D. Xu, E.L. Xu, L. Li, Industry 4.0: State of the art and future trends, *Int. J. Prod. Res.*, 56, 2018, pp. 2941–2962.
- [6] K. Martin, Innovative Competition with Chinese Characteristics. The Case of 'Made in China 2025' in Relation to the German Industry, Bachelor's Thesis, 2018, <https://openaccess.leidenuniv.nl/handle/1887/63733>, 7 September 2018
- [7] T. Shubin, P. Zhi, "Made in China 2025" and "Industrie 4.0"—In Motion Together, In *The Internet of Things*, Springer: New York, NY, USA, 2018, pp. 87–113.
- [8] M. Huimin, X. Wu, L. Yan, H. Huang, H. Wu, J. Xiong, J. Zhang, Strategic Plan of "Made in China 2025" and Its Implementation, In *Analyzing the Impacts of Industry 4.0 in Modern Business Environments*; IGI Global: Derry Township, PA, USA, 23, 2018, pp. 1–23.
- [9] Y. Liao, F. Deschamps, E. de Freitas Rocha Loures, L. F. P. Ramos, Past, present and future of Industry 4.0—A systematic literature review and research agenda proposal, *Int. J. Prod. Res.*, 55, 2017, pp. 3609–3629.
- [10] L. Monostori, Cyber-physical production systems: Roots, expectations and R&D challenges, *Procedia CIRP*, 17, 2014, pp. 9–13.
- [11] K. Zhou, T. Liu, L. Zhou, Industry 4.0: Towards future industrial opportunities and challenges, In *Proceedings of the 2015 12th International Conference on Fuzzy Systems and Knowledge Discovery (FSKD)*, Zhangjiajie, China, 2015, pp. 2147–2152.
- [12] G. Lanza, P. Nyhuis, S. M. Ansari, T. Kuprat, C. Liebrecht, Befähigungs-und Einführungsstrategien für Industrie 4.0. *ZWF Zeitschrift Wirtschaftlichen Fabrikbetrieb*, 111, 2016, pp. 76–79.

- [13] K. Lichtblau, V. Stich, R. Bertenrath, M. Blum, M. Bleider, A. Millack, K. Schmitt, E. Schmitz, M. Schroter, Industrie 4.0 Readiness, Impuls-Stiftung des VDMA Aachen-Köln, 52, 2015, pp. 1–77.
- [14] A. Schumacher, S. Erol, W. Sihm, A maturity model for assessing industry 4.0 readiness and maturity of manufacturing enterprises, *Procedia CIRP*, 52, 2016, pp. 161–166.
- [15] S. Munir, J. A. Stankovic, C. J. M. Liang, S. Lin, Cyber Physical System Challenges for Human-in-the-Loop Control, In Proceedings of the Presented as part of the 8th International Workshop on Feedback Computing, USENIX, San Jose, CA, USA, 4, 2013, pp. 1–4.
- [16] P. A. Hancock, R. J. Jagacinski, R. Parasuraman, C. D. Wickens, G. F. Wilson, D. B. Kaber, Human-automation interaction research: Past, present, and future, *Ergon. Des.*, 21, 2013, pp. 9–14.
- [17] B. Bidanda, P. Ariyawongrat, K. L. Needy, B. A. Norman, W. Tharmmaphornphilas, Human related issues in manufacturing cell design, implementation, and operation: A review and survey, *Comput. Ind. Eng.*, 48, 2005, pp. 507–523.
- [18] A. Roitberg, A. Perzylo, N. Somani, M. Giuliani, M. Rickert, A. Knoll, Human activity recognition in the context of industrial human-robot interaction, In Proceedings of the Signal and Information Processing Association Annual Summit and Conference (APSIPA), Siem Reap, Cambodia, 9–12 December; 10, 2014, pp. 1–10.
- [19] T. Ruppert, Sz. Jaskó, T. Holczinger, J. Abonyi, Enabling Technologies for Operator 4.0: A Survey, *APPLIED SCIENCES-BASEL* 8: 9, 2018, pp. 1650.
- [20] J. Hawksworth, R. Berriman, S. Goel, Will Robots Really Steal Our Jobs? An International Analysis of the Potential Long Term Impact of Automation, 2018, http://pwc.blogs.com/economics_in_business/2018/02/will-robots-really-steal-our-jobs.html, 20 July 2018
- [21] M. Reuter, H. Oberc, M. Wannöffel, D. Kreimeier, J. Klippert, P. Pawlicki, B. Kuhlenkötter, Learning factories' trainings as an enabler of proactive workers' participation regarding Industrie 4.0, *Procedia Manufacturing*, 9, 2017, pp. 354–360.
- [22] S. Erol, A. Jaeger, P. Hold, K. Ott, W. Sihm, Tangible Industry 4.0: a scenario-based approach to learning for the future production, *Procedia CIRP*, 54, 2016, pp. 113–118.
- [23] C. Prinz, F. Morlock, S. Freith, N. Kreggenfiels, D. Kreimeier, B. Kuhlenkoetter, Learning factory modules for smart factories in Industrie 4.0, *Procedia CIRP*, 54, 2016, pp. 7–12.
- [24] S. Simons, P. Abé, S. Nesarb, Learning in the AutFab – the fully automated Industrie 4.0 learning factory of the University of Applied Sciences Darmstadt, *Procedia Manufacturing*, 9, 2017, pp. 81–88.
- [25] M. Elbestawi, D. Centea I. Singh, T. Wanyama, SEPT Learning Factory for Industry 4.0 Education and Applied Research, *Procedia Manufacturing*, 23, 2018, pp. 249–254.
- [26] E. Abele, G. Chryssolouris, W. Sihm, J. Metternich, H. ElMaraghy, G. Seliger, G. Sivard, W. ElMaraghy, V. Hummel, M. Tisch, S. Seifermann, Learning factories for future oriented research and education in manufacturing, *CIRP Annals*, 66 (2) (2017), pp. 803–826.
- [27] M. Tisch, C. Hertle, J. Cachay, E. Abele, J. Metternich, R. Tenberg, A systematic approach on developing action-oriented, competency-based learning factories, *Procedia CIRP*, 7, 2013, pp. 580–585.
- [28] D. Mavrikios, K. Sipsas, K. Smparounis, L. Rentzos, G. Chryssolouris, A Web-based application for classifying teaching and learning factories, *Procedia Manufacturing*, 9, 2017, pp. 222–228.
- [29] M. Tisch, J. Metternich, Potentials and limits of learning factories in research, innovation transfer, education, and training, *Procedia Manufacturing*, 9, 2017, pp. 89–96.