Productive4.0
Holistic Innovations to Open the Potentials of Digital Industry

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Abstract

While the digitalization of our everyday lives and the fourth industrial revolution are in full swing, the Productive4.0 project turned out to be a real digital push for the industry in Europe. As the biggest in the history of European co-funded projects, Productive4.0 mobilized 109 European partners to work on hands-on solutions for the digital future. The aim of Productive4.0 was to create a value chain and cross-industry user platform and thus to promote the digital networking of manufacturing companies, production machines, and products.

INTRODUCTION

Productive4.0 (see Figure 1) has been a pan-European project that took a major step towards a hands-on approach of digitalizing the European industry with the focus on three pillars, namely a) Digital Production (DP), b) Supply Chain Networks (SCN), and c) Product Life Cycle Management (PLM). Covering these fields is part of a new approach for introducing seamless automation and network solutions as well as enhancing the transparency of data, their consistence and overall efficiency. That the three pillars collaborate and influence each other in a lot of ways and on a number of levels has been taken into account. The approach has covered all industrial domains, from automotive to robotics.

With its central role in the project, Infineon Technologies A.G. contributed with both its experience in coordinating large-scale projects, as well as with technical expertise from its own innovation areas. And the benefits to Infineon are substantial in terms of both technology and visibility. As such, Infineon can now point to a successful coordination of a major international project.

This paper presents the main outcomes of the Productive4.0 project in terms of a) the digital reference ontology, and b) results reflected on the project use cases. Last, the paper explains how Productive4.0 has opened the gates for further boosting digitalization through the introduction of even more novel technologies in an already digitalized industry.

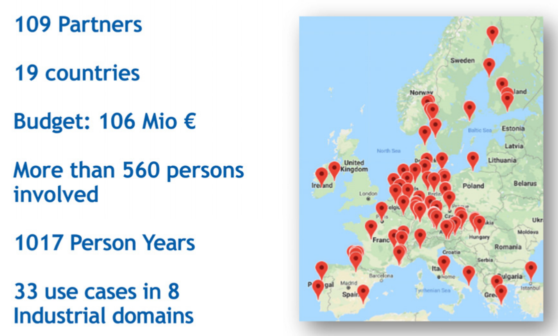

Fig. 1. Key numbers and partner map of Productive4.0 project.

THE DIGITAL REFERENCE ONTOLOGY

The Digital Reference ontology, introduced by Productive4.0, is the Semantic Web mirror of the semiconductor industry and of supply chains containing semiconductors. This digital mirror, organized in topic clusters (lobes), enables digital pictures of the natural world to be read by machines and understood by humans alike, which is necessary for digital production, digital supply chain networks, and digital product lifecycle management. It contains almost 1000 classes and their relationships that describe concepts in different domains. Currently, the digital reference is the overarching ontology containing several sub-ontologies that represent hierarchies, processes, and taxonomies e.g., product ontology, sensor ontology, organization ontology and process ontology.

An overview of the visualized domains of the Digital Reference is presented in Figure 2. The scale of the digital reference continues to expand with the development and the integration of other relevant ontologies – e.g., in the SC³ project – semantically connected semiconductor supply chains, which is a corporate support action (CSA) of ECSEL, further opening the doors for the digital industry based in this holistic innovation.

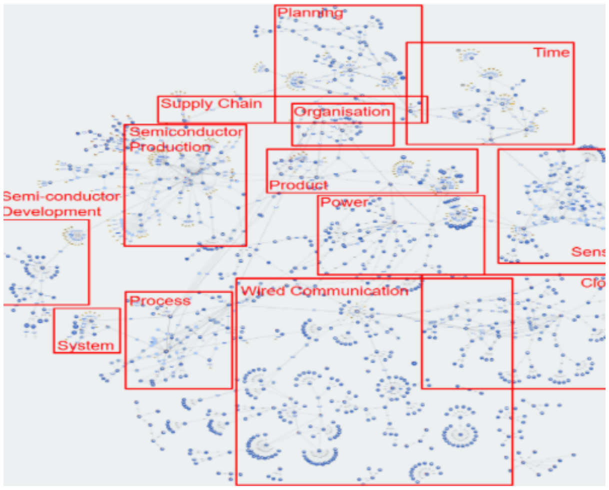

Fig. 2. Overview of the visualized domains of the Digital Reference (see w3id.org/ecsel-dr for detailed view)

DIGITALIZATION USE CASES IN INDUSTRY

Infineon benefited from the project and the work in collaboration with research institutions, universities, and partners highly specialized in automation and digitization to open new ways in the fields of factory automation and to create demonstrators for future high-volume production e.g., for ultrathin wafers (see Figure 4) at Infineon's manufacturing facilities Dresden, Regensburg, and Villach. Thus, important gaps and white spots in factory automation could be closed. Examples are automated processes for controlled and automated thin wafer handling and first demonstrators for automated packaging of wafers in shipping boxes.

Using technologies from the Internet of Things, the existing manufacturing execution system of the Dresden factory was brought to a level with the capability to extract billions of data points out of the complex manufacturing process across all locations, enabling advanced analytics. This is a significant step to increase the digitization level of manufacturing and can be used as basis for machine learning and deep learning. Infineon created a so-called data lake, a repository of structured and unstructured data. Important manufacturing data is collected, transformed, and loaded into a structured database for possible use by data scientists. Figure 3 shows a dashboard based on the excerpt of the data lake, used in production.

The established data lake is also available to other manufacturing facilities at Infineon and supports the engineers for networking between the different wafer factories and for improving the overall supply chains.

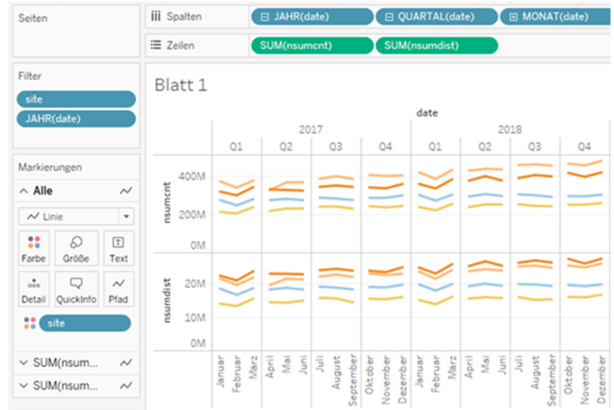

Fig. 3. Dashboard based on an excerpt of a data lake.

To enhance the automation level in manufacturing, demonstrators for an adaptive mobile robotic platform have been designed and tested for multiple tasks of future production

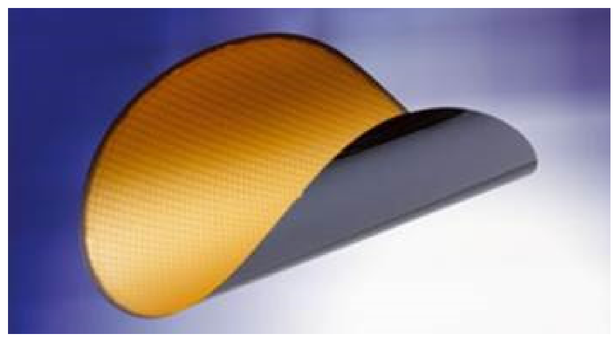

Fig. 4: Ultrathin wafers for superior electrical switching conditions

Adaptive robotic systems will be a next step in factory automation. These robotic systems can process different tasks e.g., material transportation or working on a table for special maintenance tasks. To combine different tasks in one system will be an important step towards the automation of workflows in maintenance areas. This first demonstrator showed, how those systems can be designed.

Important frameworks for processes that could not be automated so far, such as special thin wafer processes and processes to control the contamination level of products in wafer containers, were developed as part of essential research focusing on zero-defect production.

Figure 5 shows a first demonstrator of a fully automated wafer packaging process which was constructed and tested during the project

Fig. 5. Demonstrator of a fully automated wafer packaging process.

Novel algorithms and scheduling approaches were also developed in the project, which are now rolled out to front-end plants across many departments at different Infineon sites (see Figure. 6).

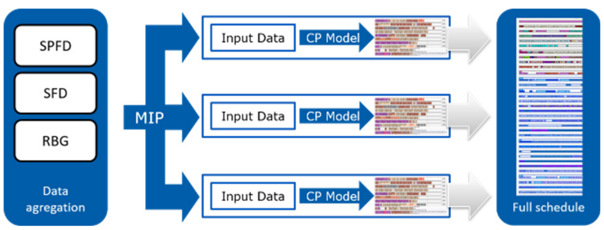

Fig. 6. Demonstrator for lot planning.

For this, data structures and inputs for the defined areas have been created. The required data including process times for all process steps in the network have been aggregated and parsed into the data structure. A combination of mixed integer programming and constraint programming has been used to train complex optimization models. A data network structure was established, resulting in a new concept with reduced complexity of mathematical models for computational solvers. This allowed all steps in the defined areas to be modeled. Based on the proven functionality of the first model, the scope of research regarding scheduling was expanded to include not only the current inventory of equipment, but also additional lots in other units in the production areas. As a result, a combined method was developed to schedule all lots that are actually in the defined area or will arrive soon. Based on this, all processes were combined, the data aggregated and a demonstrator for a production area was established.

The implementation of a task management system in the production at Infineon Dresden enables employees to greatly optimize their workflows and concentrate on more value-added activities, which had led to significant productivity increases. Maintenance workers are now able to get a complete overview at any time during their shifts. The task manager is created on a standard mobile phone application without camera functions and gives the experts on shift important information e.g., the different task, the task number, status, and the actual progress of each task (see Figure 7). Other information e.g., the shortest way to optimize the time to search of the tools or problems in the line can also be supplied by the task manager

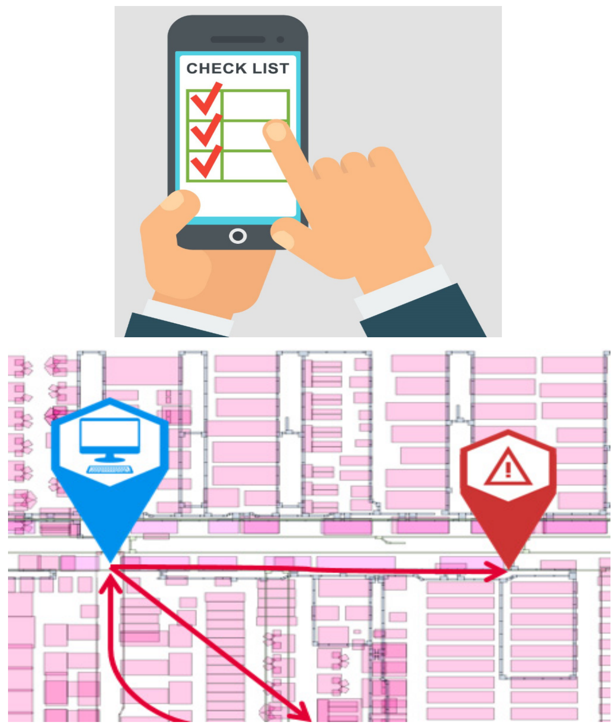

Fig. 7. Implementation of a task management system in production.

The excellent cooperation with the project partners is particularly noteworthy, which led to several novel ideas and further projects. For example, some of the results developed in Productive4.0 were an excellent basis for follow-up projects, like EU projects iDev40 and Arrowhead Tools, to further digitize production in Europe. In addition, many scientific publications on factory automation and production digitization have been published.

At the CS ManTech conference, we will present the Productive4.0 project, focusing on industrial use cases including large industries with an international reputation (OEMs and suppliers from different industrial domains, e.g., mechanical/electrical engineering, machinery, semiconductor industry, manufacturing, chemical industry, and finance/banking)

Fig. 8. Consortium meeting in Budapest, before Covid 19

More details on the project and the digital use cases can be found on the project web site (https://productive40.eu/) and on the project YouTube channel with more than 100 videos (https://www.youtube.com/watch?v=Hq0HTPrlPGI).

CONCLUSION

Productive4.0 brought together 109 key European Players from industry and academia for holistic innovations to open the potentials of the Digital Industry. The Digital Reference emerged, and the potential has been demonstrated in several use cases. As an outcome of the project, we expect new smaller consortia to conduct new product-oriented and funding-related projects in specific areas (see projects like SC^3, Enerman, and CoyPu [7,8,9]. Productive4.0, being a large platform, provided the ideal basis for such developments.

The methods and technologies developed in this project within the semiconductor production domain were mainly based on silicon materials but are independent of the substrate material and can therefore be transferred to other materials such as compound semiconductors.

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ACRONYMS

DP : Digital Production
SCN: Supply Chain Networks
PLM: Product Life Cycle Management
CSA: Corporate Support Action
ECSEL: Electronics Components and Systems for European Leadership