INTERACTIVE SYSTEM FOR DESIGN OF FACTORIES OF THE FUTURE

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Abstract

Production and logistics systems are currently undergoing revolutionary changes. They are gaining new features and functionalities. We are finally starting to perceive production as a holonic system. Machines, robots and products are becoming intelligent and advanced information and communication technologies are becoming the central nervous systems of the future production. In the near future, artificial intelligence will take on many management and decision-making functions in production. Production systems will be able to learn from their past operations. Virtualization will bring massive deployment of sensors in production, allowing us to collect large amounts of data, generate information, process these and use them to create and apply new knowledge. The new production environment will maintain and operate its virtual image using the technologies of the Internet of Manufacturing and clouds. Without intelligent and adaptive production and logistics, companies will not be able to operate effectively in the competitive environment of global markets. The effort to speed up and streamline the design cycle of such intelligent production and logistics systems leads to the current trend of digitalization and virtual design of such systems. Attempts to improve the level of visualization, transparency, presentation of design outputs, as well as the effort to assess the feasibility of the proposed solution in a complex way and identify potential collisions in the proposed system while still at the designing stage, lead to the creation and utilization of 3D models of individual objects as well as complex production and logistic systems. In the article, the authors describe Interactive Designing System CEIT Table, which represents an integrated solution for the support of intuitive, team-oriented design of intelligent production and logistics systems of plants of the future. By a suitable combination of software and hardware, it is possible to accelerate and optimize the entire designing process while keeping the option of team decision-making. The article describes the basic concept of CEIT Factory Twin which is intensively being built at the authors' workplace, one of the main parts being the interactive designing system CEIT Table.

Keywords: Factories of the future, factory twin, smart factory

1. INTRODUCTION

Growing competitiveness pressure requires immediate response, often even in the form of an entire business model change [1]. So that is necessary to transform traditional approaches production systems to digital production systems [2]. Production and logistics systems of the future must be adaptable, able to adapt autonomously, actively and promptly to sudden and unexpected changes originating in their environment and reaching beyond the boundaries of the predefined functions of the system. Such system must have the capability of changing not just its structure but also its functions and capacities. The basic characteristics of adaptive production a logistics system of the future have been defined by Koren [3]. These are:

- Customization - flexibility limited to a family of parts or products,
- Scalability - capability to easily modify the capacity of the production and logistics system by adding or removing sources or by changing the reconfigurable elements of the system,
- Convertibility - capability to easily transform the functionality of existing systems, equipment and controlling systems in order to meet new production requirements,

- Modularity - capability to integrate operating functions into units that can be manipulated among alternative production and logistics schemes to achieve optimal results,
- Integrability - capability to rapidly and precisely integrate modules using a set of mechanical, information and controlling interfaces enabling integration and communication,
- Diagnosability - capability to automatically diagnose current state of a system and its management for detection and diagnostics of the root causes of the equipment or product defects and a rapid correction of operational issues.

These changes, initiated by the fourth industrial revolution and by the attempts to build intelligent production plants (Smart Factories), must be taken into consideration by industrial engineering, technology planning, planning, management and optimization of production and logistics processes. Design, management and optimization of the production systems of the future will no longer be possible without the use of advanced technologies. Future production systems must have completely new features such as self-organization, reconfigurability, autonomy, self-optimization, self-replicability, learning ability and autonomous operation with creation and exploitation of knowledge. The design of production systems is linked to the use of a wide range of modern technologies. These are nowadays known as Advanced Industrial Engineering. Production systems today are designed in virtual reality, computer simulation has become a common part of such systems, artificial reality methods are increasingly used.

2. FACTORY TWIN

Factory Twin represents real system and its behaviour. Production system consists of groups of physical devices, extended by a social system (workers) and a production management system. Device operation in the sense of a digital twin is a concept, that mitigates creation of a superior system - a complex enterprise solution developed by CEIT and implemented under the name Factory Twin (digital twin of an enterprise). Intelligent enterprise, in English known as a Smart Factory, is seen by CEIT as a symbiotic interconnection of three worlds: real, virtual and digital (**Figure 1**). Digital enterprise is a 3D digital representation of a real enterprise that enables prompt and effective design or optimization of manufacturing disposition and production and logistics processes. Data from a real enterprise acquired through omnipresent sensors are the basis of the virtual enterprise which is a data representation of a real operation and with the support of artificial intelligence it represents a prerequisite for autonomous control and self-optimization.

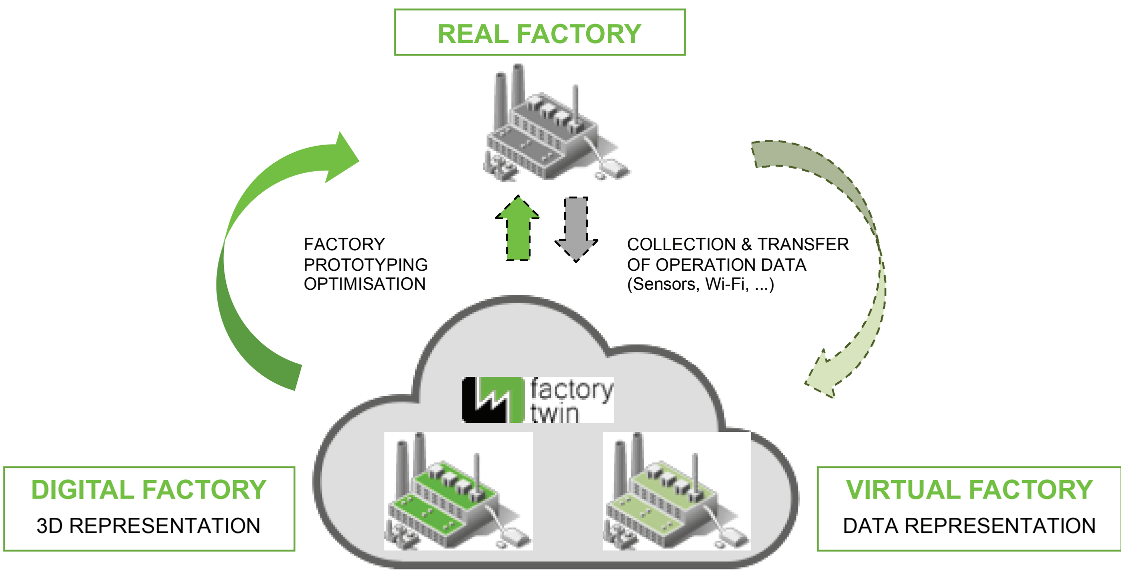

Figure 1 Factory Twin concept

The symbiosis of a real, digital and virtual enterprise is represented in Factory Twin, and as such it has also become synonymous with the intelligent enterprise of the future. At present, CEIT is developing its version for reconfigurable logistics. Factory Twin provides 3D monitoring and tools for analysing the operation of the production and logistics system (both automatic and manual logistics), which brings enormous potential for optimizing the whole system based on facts. It also provides the ability to navigate in a real environment or locate all dynamic elements of the production environment. Factory Twin enables virtual training of employees in the Digital Twin enterprise environment, as well as a guidance in the implementation of business processes (e.g. maintenance).

3. MAIN BENEFITS OF THE FACTORY TWIN SOLUTION

- Underpinning processes from the design of production and logistics system to autonomous management and optimization.
- Collecting and continuous assessment of data and information as a basis for streamlining and optimization.
- Decision-making based on facts and real-time configuration of the system.
- Quick access to comprehensive and relevant information.
- Systematic capture of the most valuable asset - business knowledge.
- Reduction of error costs.
- Reduction of wastage costs (inefficiency, ...).
- Comprehensive picture of the current state of production and logistics.

4. CEIT SMART FACTORY

CEIT Smart Factory is a Digital Factory extension that adds Virtual Factory to the concept to create, in a virtual environment, what we in CEIT call the Digital Factory Twin.

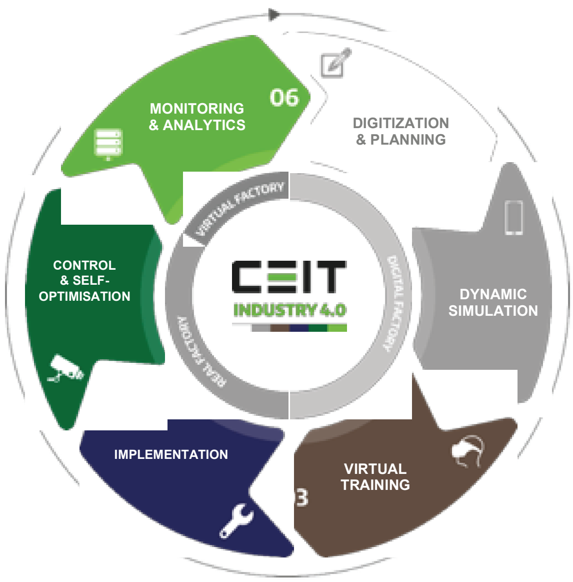

Figure 2 CEIT Smart Factory complex

CEIT today is developing a comprehensive solution for the intelligent plant of the future (Smart Factory) from A to Z (**Figure 2**). The process begins with digitization and planning in the 3D environment of the digital enterprise. The proposal is then rationalized and optimized with support of dynamic simulation. The advantages of dynamic simulation in comparison to static capacity calculation lie in more precise analyses of the production system [4]. Larger amount of created variants of dynamic system causes higher probability to find the most suitable solution [5]. By designing and verifying in the Factory Twin environment, the user can reduce the production lead time to the minimum and avoid expensive complications. Before the actual implementation of changes begins, the company can run virtual training for the key processes and prepare staff for the real operation to shorten the learning curve and thus the start-up time. Virtual training takes place in the 3D Factory Twin environment, which is a digital twin of the real system. After the whole solution is designed, optimized, and the virtual training is running, CEIT specialists implement the proposed solutions in the corporate environment - from deploying complex automated logistics systems to delivering tailor-made production lines. The operation of these solutions is autonomous, they can self-optimize in real time, communicate with the control system in the company and can respond to production changes in real-time. The last step is automated data collection, monitoring, and analytics that bring a factual digital image of the actual business environment in the Factory Twin environment, which, with the support of analytical tools, makes it possible to further improve the whole system.

5. SUPPORT FOR DESIGNING PRODUCTION SYSTEMS IN VIRTUAL ENVIRONMENT

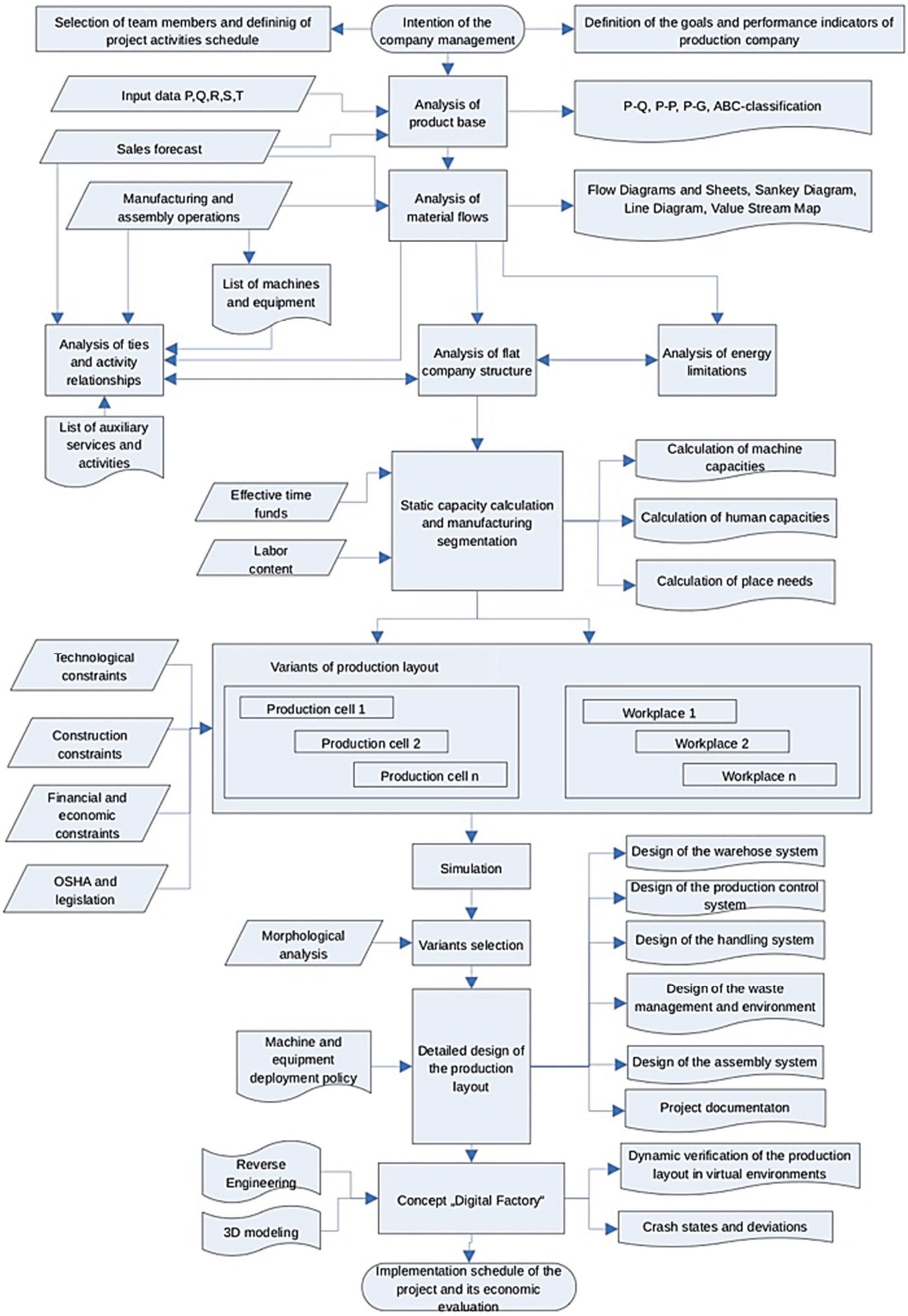

Figure 3 Algorithm for 3D design of production systems developed at the authors' workplace

Designing in a virtual environment should respect the requirement for teamwork in the individual designing steps. This requires ensuring the appropriate visualization of partial outputs from the design and the possibility to interact and easily modify the design and carry out the modifications, with subsequent availability of feedback on the consequences of the changes made to the basic parameters of the production layout. The principle of designing production systems is illustrated by the following algorithm (**Figure 3**).

The software product CEIT Table (**Figure 4**) represents such integrated solution to support intuitive, team-oriented design of production systems. By using the appropriate combination of software and hardware, it is possible to accelerate and optimize the whole designing process while maintaining the possibilities of team decision-making.

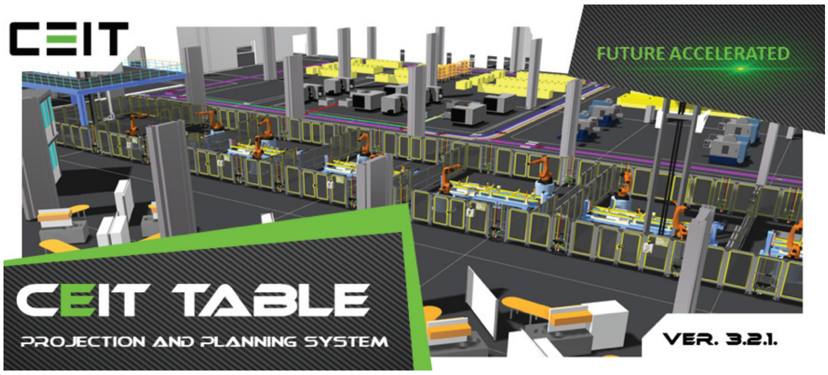

Figure 4 Designing the production disposition using CEIT Table system

CEIT Table program environment includes tools to support the basic activities associated with designing a production layout:

Layout design

- Data import in DGN, DWG, FBX, LOD_FBX format
- Physical properties of solid bodies - collision control
- Generating service areas based on valid regulations
- Collision control
- Assessment of the production disposition areas (manufacturing, warehouse, logistics)
- Creation of visualization
- Virtual tour

Planning parts in workplaces

- Import of BOM in XLS format
- Planning (build-up area) of the workplace linked with the capacity assessment of the workplace areas
- Calculation of the part consumption in the workplace
- Calculation of the part turnover and the interval

Logistics supply planning

- Generating the logistics network and material flow
- Visualization of material flows (Sankey diagram, Spaghetti diagram)
- Parameterization of transport flows (type of handling device, speed, capacity…)
- Generating and dimensioning supply cycles
- Evaluating transport flows (length, time, capacity requirement of handling devices)

Operation planning

- Import of operations in XLS format
- Scheduling operations by individual workplaces
- Line balancing
- Capacity dimensioning of operators

Operation standardization

- Operation standardization using the MTM-UAS methodology
- Calculation of operator’s load
- Linking the operation to the parts
- Operators’ movement visualization

Ergonomics assessment

- Workplace screening in virtual environment - positions, reach zones
- Manipulated weight control
- Linking the operation to the parts

Of course, the visualization of the production system is conditioned by the existence of individual object models. At the same time, a link between the 2D model and the 3D representation is needed. The software itself contains libraries of 2D/3D objects that are divided into different categories (transport, assembly, production, warehouses, building elements, areas, handling units, etc.). The DMU - Digital Mock Up modelling of production machinery and equipment and FMU - Factory Mock Up have been developed in the authors’ workplace to support the interactive design of manufacturing systems.

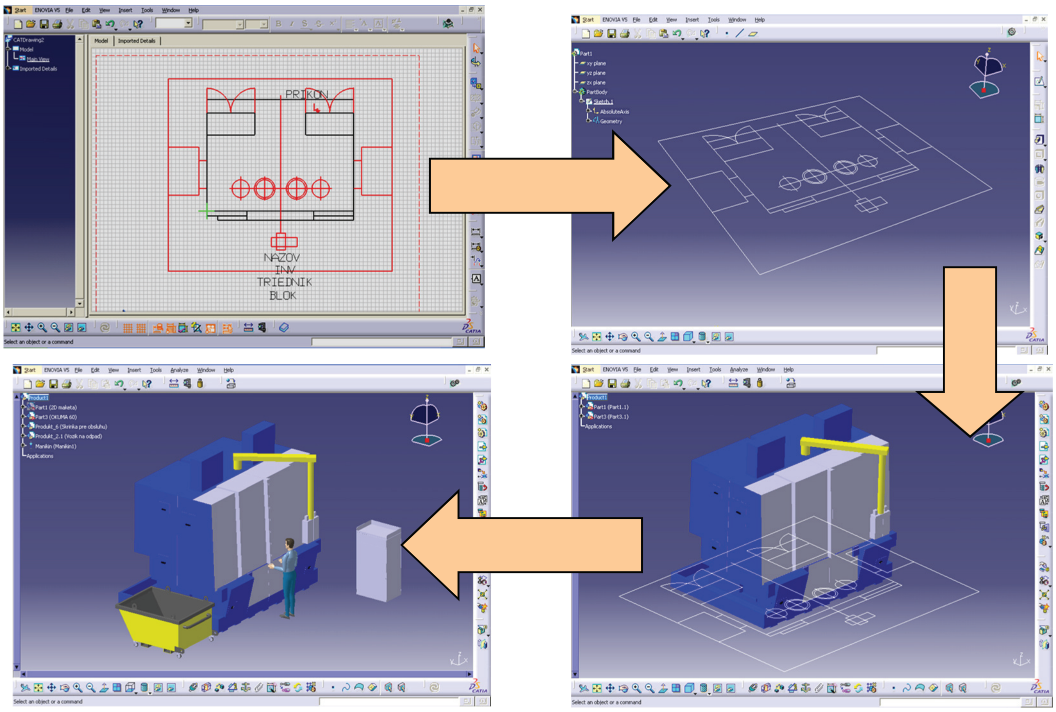

Figure 5 Methodology for creating 2D and 3D models to support 3D design of VS

In addition to solving the spatial layout of objects in the production workshop, the software also provides basic features to support the optimization of the proposed layout by defining transport relationships between individual workplaces. The disposition assessment implementation is based on the total value of the transport performance and transport distances. The software offers an I - D diagram (Intensity - Distance diagram) to assess the proposed disposition and allows for automatic control of defined safety distances between the various production system objects [6]. The material flow is represented by a Sankey diagram displayed directly in the 2D manufacturing disposition. With any change in spatial layout the Sankey diagram is updated as well as the quality assessment of the proposed layout, allowing designers to continually evaluate the consequences of the layout changes on the resulting production layout.

6. CONCLUSION

Nowadays, production systems are becoming more complex and more demanding of information processing requirements. To ensure the functionality of costly systems, it is necessary to develop complex models and analyses to ensure the required performance after their implementation. Only few instruments and technologies can be involved in the integration of widespread operations, so called design of a full system. When creating a virtual workplace, it is necessary to integrate different types of software, modelling tools and methodologies in order to support solutions across a range of issues in the manufacturing field. This article describes the interactive design system CEIT Table, which is a part of the CEIT Smart Factory concept being developed and it supports team approach to the 3D design of production dispositions. This system represents a complex solution to the problem of involvement of the project team in the design of the layout, the visualization of the individual steps of the solution and the possibility of interactive correction of the proposed disposition with the possibility of assessing the quality of the proposed disposition in each individual step of the solution. This complex system is currently being developed at the CEIT workplace, while solving the linking of the mentioned system to a reverse engineering system (3D laser scanning technology), which is used to digitize real objects of production systems, i.e. their transformation into digital 3D models, with a system of dynamic process verification using the computer simulation.

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