CHANGE IN CONCEPT FROM CONVENTIONAL TO DIGITAL FACTORY OF THE FUTURE

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The study of the Digital Factory consists of the design of an automated manufacturing system with elements of autonomy within the concept of Industry 4.0. This study origin was inspired with the production of drumsticks. For the intended purposes, manufacturing system designs for Factories of Future are created. The system consists of elements that are part of the digital production with automated functions that serve to communicate and interconnect the equipment located inside the factory as well as its external parts - buildings. Together, they should create a comprehensive set of automated elements and autonomous production in Smart Future Factories.

KEYWORDS

digital factory, digital production, production systems, Industry 4.0,automated systems.

1 INTRODUCTION

In recent years, research and development centers have been actively involved in the creation and experimental verification of hardware and software environments suitable for implementing functionalities defined for building the Industry 4.0 platform.

An essential part of innovation is building a strong technological infrastructure and know-how in the form of transforming production from standalone automated units into a fully integrated automated and continuously optimized manufacturing environment, referred to as Smart Factories.

The fourth industrial revolution began in the world's most advanced economies, independently of each other and under different names. However, a common feature is that it has been prompted by the same effort to maintain and strengthen the competitiveness and technological leadership of these countries on world markets. As stated in the Czech National Initiative Program Industry 4.0, "this effort also seeks to take greater control of the entire value chain, making it very difficult in today's labor cost and availability in developed world economies. Last but not least, it seeks to address the growing socio-economic problems and face new demographic and geopolitical risks. This has led many global companies to reassess the current concepts of geographic allocation of production capacity and to systematically build a modern industrial production model" [Koderová 2016].

The Fourth Industrial Revolution resonates in EU countries primarily in response to the German Industry 4.0 initiative. Similarly, "Smart Manufacturing Leadership Coalition" in the United States, or similar programs in Japan and China. A common feature of these initiatives is the new philosophy of systemic use, integration and interconnection of a variety of technologies, while continually developing them. Automated systems and electronics have evolved into a wide range of lightweight wireless personal communication devices with ever-evolving operational, imaging, and information exchange capabilities, from remote data uploading and downloading to online data services worldwide [Elektrosmog.voxo.eu 2017, Hannover Messe 2017].

That the industry is serious about this challenge is demonstrated by the Industrial Internet Consortium [Fara 2017], initiated by the open-not-for-profit Object Management Group® (OMG®), established in 1989, consisting of both industrial and non-industrial development institutions. new technological standards, bringing significant values to thousands of vertical industrial complexes [Simsik et al. 2017].

Upgrading and linking devices creates a network that we can call intelligent. The market offers automated solutions for intelligent households and intelligent industrial buildings that are partly managed by themselves. They monitor their rooms with the help of sensors located in the rooms. Most of these homes and devices are connected over the Internet. All smart devices create data that is then shared into a shared network for mutual communication and archiving. The greater the degree of automation, the higher the comfort it brings to the user, and at the same time transfers the responsibility for managing environmental conditions from man to machine. Nowadays, the term Industry 4.0 is known almost for all manufacturing companies, automotive companies, businesses. Most of these businesses own production lines and systems that are either semi-automated or fully automated.

2 CPS ARCHITECTURE AND STANDARDIZATION TECHNOLOGY

Cyber-Physical Systems (CPS) are systems controlled or monitored by computer programs, closely interconnected and integrated over the Internet with system users. In these systems, physical and software components are closely linked, working in different spatial and temporal scales, exhibiting repetitive and different behavioural patterns, interacting with each other through a large number of connections varying depending on the task context [Onofrejova 2017].

Figure 1. Industry 4.0 interface

Examples of such systems appear across the breadth of industry, services, or public life, such as smart grid systems, autonomous automotive systems, medical monitoring, process control systems, robotic systems, automatic piloting, space technology, energy, chemical processes, health, public management, entertainment, or consumer electronics. CPS inevitably uses interdisciplinary approaches combining cybernetics with mechatronics, design and process science. Process management is associated with embedded systems, the Internet of Things, as well as all covering and integrating cloud technologies [Onofrejova 2017a,b].

CPS will be an essential building block of smart autonomous factories, capable of autonomously exchanging information, responding appropriately to good action, and controlling each other independently. Industry 4.0 anticipates mutual cooperation and communication between human - machine, man - man, machine - machine, even communication within logistics systems and products [Pandova 2016]. The entire production system and its environment - machines, production parts, sensors, computer systems - will be linked within a value chain that extends beyond the boundaries of a single company. These linked CPS will interact with each other and standardize the data using standard Internet-based communication protocols to analyze data to anticipate any errors or failures, configure themselves and adapt to changed conditions in real time [Koderová 2016, Panda et al. 2016].

The big benefit of Industry 4.0 will be the use of a large amount of disused information for faster and more accurate processing and decision making. The interconnection of products, devices, people increases the efficiency of production machines and equipment, reduces costs and does not waste resources. Smart Tracking and Transparent Processes provide companies with a constant overview that allows them to respond flexibly and quickly to changes in markets. CPS, Internet of Things, Internet Services, Big Data, Cloud Computing, Digital Manufacturing, Product Lifecycle Management Systems), Digital Twin (Figure 1) [Burke 2017, Fei et al. 2017].

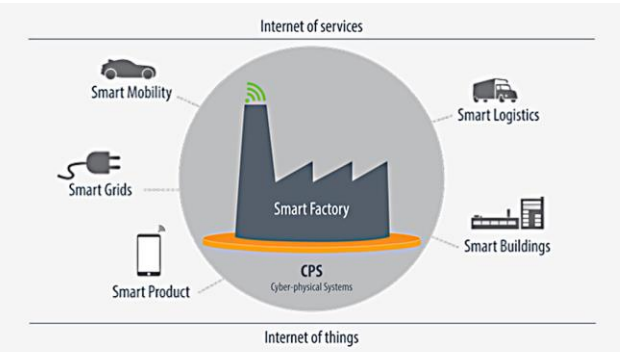


Figure 2. Connecting two worlds - a world of real physical objects and a virtual world

Part of the system is to connect two worlds - a world of real physical objects (machines, devices, robots, products, people) and a virtual world where each physical unit can be virtually represented, represented, and simulated by a software module (Figure 2). It is believed that the elements of the physical world will be linked to each other through an Internet connection where each physical element has its own individual IP address, which will be the Internet of Things (IoT). Software modules, representing physical elements in a virtual space, work together to coordinate their actions and make decisions, using services that provide each other, or that invoke via the Internet of Services (IoS).

The starting point for the proper functioning and connectivity of the Internet of Things is a basic platform with architecture enabling broadband devices to connect to the IoT [Onofrejova 2017b].

2.1 Key Features of Digital Factory In Industry 4.0

It is obvious, that Digital Factories would be characterized by a new industrial paradigm that incorporates components of future industrial development:

- **Cyber-Physical Systems**
- **Internet of Things and Services**
- **Big Data**
- **Digital Twin**
- **Cloud Computing**
- **Exponential Technologies**
- **Simulation and Visualization**
- **Product Lifecycle Management**
- **Cyber Protection**

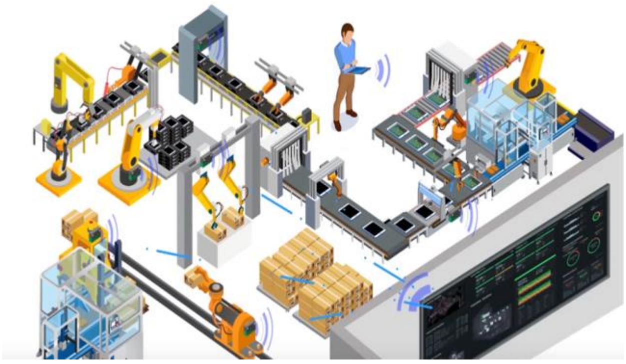


Figure 3. Connecting two worlds - a world of real physical objects and a virtual world

An Intelligent Factory in which cyber-physical systems monitor the factory's physical processes and make decentralized decisions. Physical systems become the Internet of Things, communicate and collaborate with each other and with people in real time over a wireless web (Figure 3).

Acquiring these technologies is key to developing more modern and intelligent manufacturing processes, which also include products, machines, production modules that communicate with each other, exchange information, run operations, and control each other through intelligent manufacturing environments. This concept connects the physical and virtual worlds, enabling a radical increase in productivity and production efficiency [Lasi et al. 2014].

Industry 4.0 is a transition that is based on data and automation technology that can transform every step of the production process from the supply chain and business to business and end users. The aim is to increase productivity and innovation and strengthen business in an integrated, data-driven production environment [Zou et al. 2018].

Smart factories are a step ahead of traditional automation, a system that is flexible, fully connected to the Internet, and can work with the constant flow of data coming from production systems or operations to learn and adapt to new requirements [Burke 2017].

This factory is able to integrate enterprise-wide, physical, or human resources data into production management, inventory tracking, maintenance, digital twin control, or other types of activities across the manufacturing system. This can result in a more efficient system, less downtime and greater predictability and adaptability to change, which can lead to a better competitive market position. The intelligent factory power is based on adaptation, growth and development capabilities alongside changes in organization needs:

- Change in demand for products
- New market penetration
- Research and product development
- Maintenance
- Real-time production changes [Burke 2017, Onofrejova 2017a,b].

3 CASE STUDY – CONVENTIONAL FACTORY TRANSFORMATION FOR DIGITAL FACTORY OF THE FUTURE

Software tool Autodesk Factory Design (further referred to as AFD) was used to create process optimization, design of digital manufacturing process models. The entire program is based on a CAD system. It allows digitally display and to optimize the manufacturing building and interior, as well. The benefits of AFD consist of system of several modules that are interconnected and used not only for 2D display, but also for the 3D display of manufacturing systems as closely as possible. It also allows creating and displaying a conveyor system, robotized workplaces and lines [Onofrejova 2014a]. Software package offered by AFD can be used to design workplaces, buildings, operations, or simulate logistic and material flow in 2D view.

3.1 Conventional Wood-processing Factory

AutoCAD Architecture module was used for creating digital factory design of a future production in the wood-processing industry. In this subchapter, there is offered a solution of the production process of wooden sticks (Figure 4). The product wooden sticks are specifically wooden drumsticks used in the music industry.

The initial production process begins with the entering the material into production. In this case, material remains of large pieces of potted trees (wooden logs) that are cut into smaller individual pieces to produce wooden cuttings and wooden boards suitable for further processing. The entire cutting process takes place in areas that are outside the production hall and therefore the individual cut parts must be conveyed by conveyors to the plant where these parts have to be further processed and adapted to the dimensions suitable for working. During the process of cutting the tree trunk is separated into individual boards, it is further specified which plates and cuttings are suitable for further processing. Cutting of the trunk is realized by gradual separation into the required approximate dimension in the vertical direction.

Cut pieces of wood are stacked on pallets and transported to a special room with temperature and humidity control, so that the quality of the wood is not impaired. Stacking in this room takes about 2 weeks until the moisture content of the wood reaches 15%. After this cycle, the cut wood is put into production and processed to the required size.

The third step in the manufacturing process is to make from prism a profile with perfect edges. With a small curvature, the wooden prism is removed from the process. The wooden prism is machined on a special machine that cuts the prism from all four sides. After exiting the machine, the prism is moved to the lathe where a cylindrical stick is made from the prism. Using the feeder, the sticks are moved to a control where various deficiencies on the wood surface are sought.
The following operation is to create a drumstick shape using a lathe. First, the head of the stick is turned and then the body.

Subsequently, the semi-finished product goes to operation - printing the logo and paint-coating, from where it is moved to a special conveyor on which the weight of the sticks is checked. The drumsticks are thrown out of the conveyor based on a weight testing.

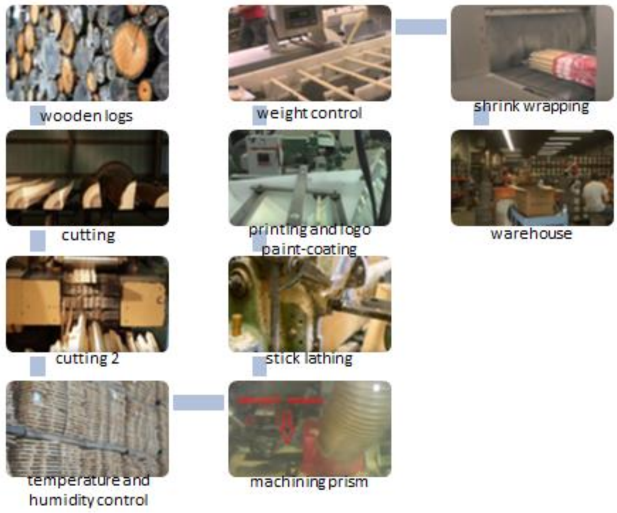


Figure 4. Production process of a drumstick

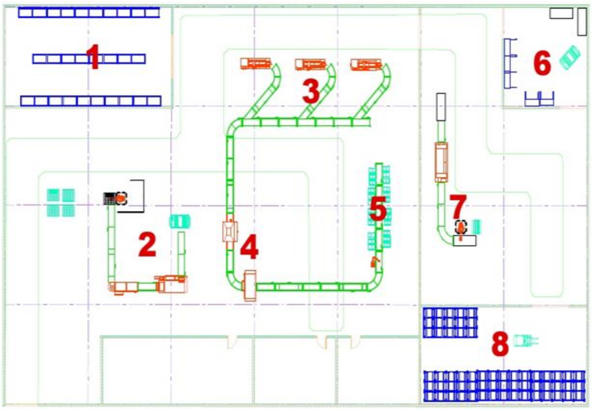
Sound is one of the most important factors needed for quality of drumsticks. Therefore, this process is performed in a specially separated room. The drumsticks are tapped with a wooden peg in front of a microphone that captures their sound, and the computer software records the kind of that sound. Subsequently, the computer software evaluates the sound and pair the best candidates to each other. Those drumsticks that do not find the match are included in the next pairing. After the pairing process, the sticks move to the final step of the manufacturing system - packaging. The packaging starts when the sticks are mounted by the worker in special cardboard packaging and the individual pairs are superimposed on each other. The sticks are tied together and slid over the conveyor belt through a shrink wrapping machine, where are wrapped in a foil due to warm air in a hot air chamber or a tunnel. After passing the tunnel, the drumsticks continue to the carton packaging process and then subsequently are taken to the warehouse.

3.2 Digital Wood-processing Factory In Industry 4.0 Concept

The aim of this paper was to create the layout of the machines and equipment used in the manufacture of wooden drumsticks with the innovative elements characteristic for Industry 4.0 concept.

The created design consists of three manufacturing work stations, two cutting and two control stations and one packaging station (Figure 5). The production process in this variant starts in the drying room (position 1), from where unprocessed wooden logs are transferred using automatic guided vehicles (AGV) to station 2. There, an automated robot and conveyor belt are activated using the proximity sensor. The wooden logs are justified and then formed into a shape of wooden cylinder. After this treatment, the wooden cylinders are directed to the mechanical treatment (station 3), the semi-finished products are moved to station 4 and subsequently are transferred to station 5.

Station 6 is a control station where a sound tests and subsequent pairing are performed. Using the AGV, semi-finished products are moved to station 7, where packaging is performed. The following process after packing is the removal of loaded pallets to the warehouse. There, the products are based on stacking units and then removed as needed.



1. Drying room
2. Automated robot and conveyor belt
3. Mechanical treatment
4. Paint-coating and labelling station
5. Weight control station
6. Sound control station
7. Shrink wrapping station
8. Warehouse

Figure 5. Layout of Digital factory for drumstick production

Over the past few years, a number of different types of sensors have been implemented in the industry and so far. Sensors in the IoT (Internet of Things) platform collect, share data on a network of devices at a level that brings a kind of intelligence making the entire "ecosystem" smarter with time [Ottomotors.com 2018, Zou et al. 2018].

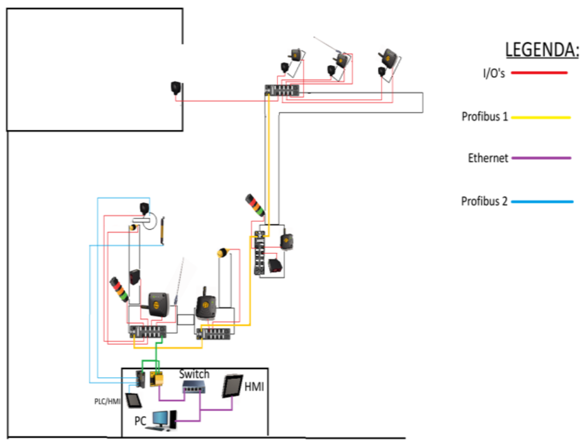


Figure 6. Network of sensors placed in particular work stations

The difference between conventional and digital factory involves new sensors, innovative technical devices, new platforms and interconnection and communication of technical devices. The intelligent automation systems offer solutions for those customers who consider and aim for safe, convenient, cost saving, smart environment and can control and manage following events:

- Lighting (and Dimming)
- Shades, Blinds (outdoor / indoor), Windows (open / close), Unlocking/ locking the doors (electrical lock), Garage doors and gates opening/ closing, etc.
- Heating, Cooling (Air Conditioning), Fan-coil Units
- Measure: Temperature, Humidity (Dew Point), Light Intensity, Concentration of Gases, etc.
- Detect: Motion, Respond to closure of any switch
- Optional device controlled by contactor or power relays
- Any device, which can be operated via communication standard RS 232, RS485, Ethernet, Infrared port
- And many others [Onofrejova 2014a].

Motion sensors located at workstations 1, 2 and 3 have the task of guiding AGV vehicles for delivery of material (Figure 6). These sensors are also located directly on vehicles. Capacity sensors are located at the end of the conveyors of workplace 2 (Figure 5). Their task is to capture the amount of material located in the neighbourhood.

If the material came into and was placed into portable baskets, their job would be to send a pallet with another batch or empty basket according to requirements. A material flow sensor (encoder) is connected to each machine, indicating the speed of the material flow.

4 CONCLUSIONS

Ambient intelligence will play a very important role in new effective production systems. Savings in costs, improving safety and the whole management in a factory will enforce its competitiveness. Applications of intelligent systems, thus creating intelligent environments is expecting to have growing tendency in increasing the efficiency and effectiveness of internal processes. Companies want to manage the business intelligently and reduce costs, but they are already considering solutions to replace the shortage of employees.

The focus in the paper consisted in transformation of conventional to digital factory implemented with new sensors, innovative technical devices, new platforms and interconnection and communication of technical devices. Such system offers solutions for those customers who consider and aim for safe, convenient, cost saving, smart environment with automated control. Change in production units may cause change in the layout and material flow and cost calculations, what will be evaluated in further study in Autocad Factory Flow software.

According to Ministry of Economy of Slovak Republic, 14% of companies started to apply concept Industry 4.0. The need for change has enabled more companies to take the first steps and build their own experiences and effort in changes put 31% of companies in 2018 against 15% last year. Mainly companies with Slovak capital are represented in this category. Conversely, companies that have not yet started the application are half the number of previous years, their share dropped from 25% in 2017 to 11% in year 2018. According to the survey, one third of enterprises already have the Industry 4.0 strategy, but firms with foreign capital predominate in this category. Businesses are largely implementing the solutions themselves, without external co-operation (60%), only 11% work with external suppliers. Most companies are still in the process of implementing rather isolated measures focusing on individual optimization goals without a more comprehensive strategy.

Obviously, Industry 4.0 is becoming a serious task in Slovakia. However, a speed of its adaptation and implementation to businesses depends on investment and varies among big and medium and small enterprises. A solution for small and medium enterprises could rise in the situation when our small and medium-sized enterprises become part of the experimental "Test-bed" or Industrial Lighthouse, whether funded from domestic sources or from HORIZONT international projects. Nowadays, industry inevitably needs infrastructure and tools to help it successfully transform. The expected support is the smart industry Action plan approved by the government of Slovak Republic.

It is good that this topic is becoming daily matter, industrial and business sphere comment on it and many contribute. It is certainly right because of its wide impact this philosophy must penetrate the minds of the whole society. Its adoption will bring not only major challenges, but also great opportunities for industry. Ignoring this new reality would lead to a gradual loss of competitiveness not only of individual firms but also of the whole economy of the state as understood by developed countries of the world.

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