THE SMART FACTORY WITH A PART PRODUCTION CONCEPT IN HIGHER EDUCATION

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ABSTRACT

The 4th industrial revolution was responsible for the formation of a new science. In Germany, the new science was named Industry 4.0. The new jobs with the titles: Architect Industry 4.0 (or digitalization, Internet of Things ...), Consultant Industry 4.0, Engineer Industry 4.0, etc., were created. Technical schools have begun offering new subjects for Industry 4.0.

A short description of the business model has been written which brings significant upgrades across all the business functions. The interactional block diagram of the manufacturing and logistics CPS (Cyber Physical Systems) has been drawn and described.

The factory of the 4th revolution called the Smart Factory is the synthesis of the 3rd Industrial Revolution systems with the upgraded process feedback loop. The new system - Smart Factory, was built using the basic units - islands and IIoT systems, which are the synthesis of manufacturing, handling, assembly, logistic and control, machines, tools, products, PLM-CAx systems, ERP, MES, SCADA and Process systems. The biggest novelty in production is the decentralized logistics of the products which navigate themselves.

The biggest advantage of the Smart Factory is the ability that staff can learn the processes much better. The longer they learn, the more they know and more added value they produce. Therefore, the Smart Factory is built for people who work to seventy years of age and older, and every day they become smarter.

INTRODUCTION

In Germany, there arose new workplaces called: CDO - Chief Digital Officer, Project manager Industry 4.0 (or digitalization, IIoT…), Architect Industry 4.0, Consultant Industry 4.0, Engineer Industry 4.0, etc. On the technical schools arising new objects of Industry 4.0, the habilitations of the lecturers and teachers for the objects of Industry 4.0 are performed. The new researchers Industry 4.0 are making the research projects on Industry 4.0. The new science Industry 4.0 came into existence. Basically it is a synthesis of mechanical engineering, electrotechnics, informatics, organization, logistics and education. The whole life education process has never been so important and part of the profession.

The 3rd industrial revolution began in 1969 with the development of the first PLC (Programmable Logic Controller) – a computer specialized for machine control. In the academic field the revolution was started by the Slovenian Professor Janez Peklenik in 1964, who established the world's first cathedra for computer controlled machines at the University of Birmingham. In the 1970's the concept CIM (Computer Integrated Manufacturing) was established. The production automation and computer aided development of CIM based systems were developed in 1980's. The business information systems ERP (Enterprise Resource Planning) and the Internet were also developed within this time period. Around 2010, all the developed automation and information systems reached their maturity. In 2012, the German government formed a group of consultants who established the next step of industrial development concept under the name Industry 4.0.

The concept of Smart Factory as a factory of the 4th revolution is based on the synthesis of the systems developed in the 3rd revolution which was also called connectivity. In reality nearly all the systems will need to be changed and upgraded to allow a synthesis, not only the connection of them. The particular focus is made on process feedback loops which include the real time visualization of the production processes. The production working processes are visualized through the use of analogue sensors where the signals are measured and visualized what is also called digitalization. The production systems upgraded with connectivity and digitalization are called CPS (Cyber Physical Systems). With the integration of the internet and the cloud we also got the systems called IIoT (Industrial Internet of Things). The biggest novelty in the production is the decentralized logistics of the products which navigate themselves.

THE MAIN ABBREVIATIONS OF THE 4TH REVOLUTION

- 2D and bar code - a contrast lines or fields with an encoded record of alphanumeric and other characters for optimal automatic reading
- AGV – Automated Guided Vehicle – an automated vehicle for transport in the production
- BDE – Betrieb Daten Erfassung - a program for the automatic collecting and analysing of production data
- CAx – Computer Aided x (programs) - a common acronym for the group of programs: CAD - Computer Aided design, CAM - Computer Aided Manufacturing, CAE - Computer Aided Engineering, CAP - Computer Aided Planning, CAQ Computer Aided Quality assurance
- CNC – Computer Numerical Control - an electronic controller for controlling the machine tools
- CPS – Cyber Physical System - a new expression for the digitized smart systems
- ERP – Enterprise Resource Planning – a business information system with a focus on production and logistics
- GPS – Global Positioning System - systems for satellite location determination
- IIoT – Industrial Internet of Things - a wireless network connected to physical products and tools with built-in computers or RFID cards, mounted in the machine and communicating with each other and with the machines, people and programs
- MDE – Maschinen Daten Erfassung - a program for the visualization and analysis of the machine processes
- MES – Manufacturing Execution System - a system for the analysis of production processes
- NFC – Near Field Communication – a wireless communication for transferring data from the passive RFID card and others, at a distance of up to 10 cm, built mainly in smartphones
- OEE – Overall Equipment Effectiveness – the factors of relative production effectiveness that simply show the significant utilization of the production systems
- PLC – Programmable Logic Controller - a programmable machine control computer
- PLM – Product Lifecycle Management – a computer supported data management system of a product over its life cycle; from an idea, through its development and production to service and disassembly. The core system are the CAx programs.
- RFID – Radio Frequency Identification – a decentralized memory card for wireless reading and writing data from an antenna connected to a computer, some sensors can also be connected.

- SCADA – Supervisory Control and Data Acquisition Systems – in the part production they are a more commonly used version of the PK (Process Kontrolle -German) - monitoring system for the technological process data production, the automatic diagnostics and for generating output control signals during the process - the highest technology in production

THE BUSINESS MODEL CONCEPT

The Smart Factory of the 4th revolution with a unique part production is the upgrade of the CIM factory of the 3rd revolution and is based on:

1. The development and production of unique products
2. Development products and technological manufacturing, handling, assembly, control processes are made in development with the PLM-CAx systems
3. The basic production unit is a decentralized and highly flexible island. Some islands will be automatically formed of machines on wheels.
4. Automation and robotization will change into a collaboration of machines and persons
5. Products, tools, the machines, programs and persons will communicate with each other
6. The logistics through the smart factory will be performed using automated vesicles
7. The planning procedure of the products will be decentralized; the products will make an autonomous instantaneous decision where they are transported
8. The maintenance will be predictive, based on the measurement of the processes
9. The quality control will be performed with measurements of the manufacturing and assembly processes (not product) – in process control
10. The information systems will be decentralized, also with cloud data bases
11. The communications will be mainly wireless with agile terminals
12. Data input will be done by the voice interfaces, cameras, touch screens, RFID, 2D, bar codes
13. The manufacturing processes' data will be produced automatically with analogue and binary sensors and measurement systems
14. Education of the staff will be performed at the beginning in dual schools and then every day at the workplace of the Smart Factory

THE INTERACTIONAL BLOCK DIAGRAM OF THE CYBER PHYSICAL SYSTEMS

The production floor of the Smart Factory is divided into the basic fixed units called islands and agile (mobile) systems mostly called IIoT (Industrial Internet of Things), which independently communicate with all the systems in production (Figure 1) [1]. Between the Islands, (with the part production processes: forming, preforming, fastening, additive manufacturing (3D printing), separating, energy processing, finishing, handling, assembly and control) with the help of smart logistic machines IIoT (AGV, ...) the products are transported. They communicate through the wireless network with all the systems in production. The basic block structures of manufacturing and logistics CPS (Cyber Physical Systems) are almost identical and shown in Figure 1.

The systems are professionally described and built outwards from the basic process. The main process of product manufacturing, is the interaction between the tool (examples: turning knife, milling cutter, plastic injection mould, sheet metal forming tool, the welder, laser beam, gripper, ...) and the product.

The tool and the product are clamped in the working, handling, controlling or assembling machine mostly on the island and each of them is equipped with its own RFID card on which are stored all the data needed for the manufacturing and logistics. The programs with the technological parameters

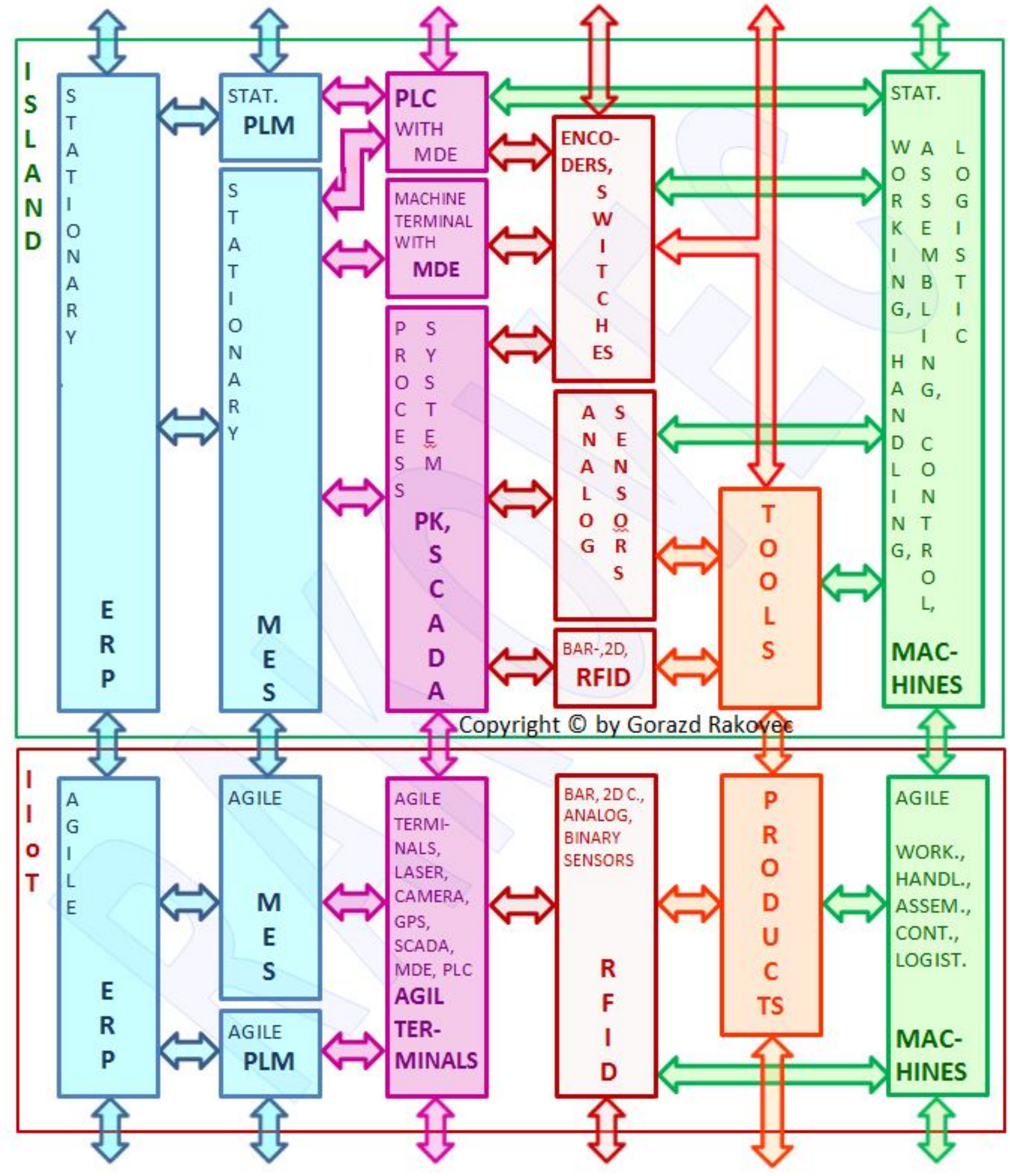

Figure 1: Stationary and agile CPS (Cyber Physical System) as a basic element of the Smart Factory with parts production in a block interactional scheme

are developed via the PLM-CAx and transferred to the RFID card via the RFID antenna tools in the development department. Antennas for RFID reading and data input are installed on all CPS systems, on mobile terminals, SCADA terminals, hardware terminals and controllers. The analogue sensors and switches are embedded into the tools and other machinery of the island. They convert the energy of the manufacturing processes into analogue and binary signals and transmit them to the input interfaces of the controllers, machine terminals and process systems.

These terminals visualize the processes in real time, make automatic diagnoses, optimize the process data, process them into the output signals which control the actuators and at the same time they write them into the data files which are also sent to the central database. On the screens, new images (curves, diagrams) of the manufacturing processes from their invisible quantities (force, pressure, temperature, acoustics, electrical current, vibration, rotation or path of the moving machine parts depending on time) are generated.

The staff who use the new visual systems begin to think in the new dimensions of the invisible processes, and therefore, think much better, and everything they make is at least one class better. They are creating improvements which are not possible without such systems. The pure new added value that is without these systems not possible is produced. Numerous analyses of the manufacturing processes are converted into indicators of quality and productivity; OEE factors are carried out in real-time with the MDE, MES, SCADA programs and the logistics programs of automatic identification, traceability, location and navigation and also more slowly and wider with the business information ERP system.

Agile (mobile) terminals with agile software MDE, SCADA, MES and ERP, built-in laser scanners, cameras, RFID, NFC and GPS interfaces interact with the RFID cards, 2D bar codes on products and other objects form agile CPS - also called IIoT.

INDUSTRY 4.0 IN THE SCHOOL

The 4th industrial revolution in the field of the Smart Factory initiated the formation of a new science. In Germany, the new science was named Industry 4.0 and therefore it will probably retain the name. The Smart Factory with the parts production must first be divided into service and production departments. The informatics department carries out the digitization of the service departments such as sales, purchasing, human resources, finance, accounting, etc., which continues its development by upgrading their work and business models based on computer tablets and clouds. In the area of sales a new science called Internet marketing was created, which will not be discussed here. The development department is engaged in the development of smart products and PLM systems' upgrades. A new department named Industry 4.0 performs the digitization in the fields of production, logistics and quality - hereinafter referred as a Smart production. In this area a new science was formed as a synthesis of mechanical engineering, electrical engineering, information technology, logistics, organization, quality, maintenance, and education. The question arises, who can make a synthesis of this entire broad interdisciplinary and complex field?

Just one of the Sciences (for example Mechanical Engineering) exceeding the capabilities of one man. Whoever works the synthesis must know and understand all the Sciences quite well, some of the main sciences even extremely well. In the field of the new Science Industry 4.0 the complete literature has not been written yet. By just studying the literature alone, however, it is not possible to learn enough about the new areas of industry. The main sources of competences are the engineers from industry who have learned, developed and applied the components of the Industry 4.0 systems for decades during the 3rd revolution period. For the area of Industry 4.0, the core competence is the development of the entire architecture of smart production, which should be well known to all the teachers in the program Industries 4.0.

In the parts' production, the large majority of the manufacturing processes are mechanical, therefore the basic knowledge is about Mechanical Engineering by focusing on an automated factory using the concepts of CIM- Computer Integrated Manufacturing developed during the third revolution. After finishing the school the engineer needs a minimum twenty -or more than thirty years of learning and working in the industry in all areas of Industry 4.0, and in the best case, in each area for a few years. The development of the production software should be included. Nobody can learn all the areas completely. The longer the engineer studies, more he knows. The length of service in the industry also means the level of competence. In the Smart Factory, the required working experience for mastering the processes has increased by at least ten years.

The development of new synthesized school subjects in the field of smart production is the function of the senior managers and consultants from industry who can make a synthesis of competencies from decades of experience and write them in the form of learning material for the new objects and the learning programme Industry 4.0. The students, who study the synthesized material, will not need to do the whole synthesis and analysis, so the objects will correspond to the level of studies in higher education. Students could learn valuable basic knowledge and concepts at school, but the real empirical skills could then be upgraded with the work in Smart manufacturing at first as a process of dual education and after that, in the Smart Factory continuously until they retire.

CONCLUSION

The Smart Factory is not smart because of the computers and process feedback loops. It is the people who are smarter. Because they are watching the measured analogue curves of invisible processes which give them the true pictures of the process, they understand the processes much better; they think in more dimensions, they are smarter and therefore they do everything better. The longer they learn, more they know and more added value they produce. Therefore, the Smart Factory is built for the people who work to seventy years of age and older. With the increasing average age of continuous learning an average level of complex employee competencies and consequently added value, competitiveness, quality and length of life will be raised.

LITERATURE

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