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Michal Balog
Angelina Iakovets
Stella Hrehová
Khrystyna Berladir *Editors*

The 2nd EAI International Conference on Automation and Control in Theory and Practice

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Editors
Michal Balog
Department of Industrial Engineering and Informatics, Faculty of Manufacturing Technologies with the seat in Prešov
Technical University of Košice
Prešov, Slovakia

Angelina Iakovets
Department of Industrial Engineering and Informatics, Faculty of Manufacturing Technologies with the seat in Prešov
Technical University of Košice
Prešov, Slovakia

Stella Hrehová
Department of Industrial Engineering and Informatics, Faculty of Manufacturing Technologies with the seat in Prešov
Technical University of Košice
Prešov, Slovakia

Khrystyna Berladir
Department of Automotive and Manufacturing Technologies, Faculty of Manufacturing Technologies with the seat in Prešov
Technical University of Košice
Prešov, Slovakia

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Preface

We are delighted to introduce the proceedings of the 2nd year of the international conference ARTEP 2024, held under the auspices of the European Alliance for Innovation (EAI). The conference was organized by the Department of Industrial Engineering and Informatics, Faculty of Manufacturing Technologies, with the seat in Prešov of the Technical University of Košice. As every year, the conference was focused on automation and management in theory and practice, especially on Industry 4.0 and 5.0 and their applications.

The conference involved researchers and experts from the European Union who use, develop, and implement intelligent technologies in practice.

The central theme of the ARTEP 2024 conference was the application of intelligent systems in industrial processes and the creation of added value for the Smart Industry in product and process innovations.

In the current state, the automation of production processes penetrates all industries. Through its activities, it increases efficiency and quality with a significant impact on its competitiveness. Today's development trends are in artificial intelligence, digitization, and robotics. The automation and digitization of the production process enable an increase in productivity and quality. At the same time, automated technological process management systems allow the monitoring and management of processes in real time. Technical process control involves designing and implementing systems that enable monitoring and controlling various process parameters such as temperature, pressure, speed, and others. These systems can be programmed to control processes automatically. Based on the measured data, they can achieve the desired results with minimal human intervention. Natural development in the field of automation and control of technological processes positively impacts safety. It can minimize the risks of accidents and positively influence the use of resources. Cybernetics has its place in the creation of algorithms, especially in the field of artificial intelligence. Imitation of people's ways of doing things, procedures, and learning is a resource in the creation of algorithms. The research area of the conference will be sustainable for many more years due to the constant development of technologies and humanity's desire for constant development.

The conference opening began with a welcome speech by the General Chair & EAI, then continued with the Workshop "Industry 4.0. and 5.0, smart technologies and trends in practice." The Workshop served as a ground for building strong cooperation between universities and manufacturing companies. The thematic area of the workshop covered acute areas of the practical side of automation that created the ground for further research.

Coordination by the steering committee: Imrich Chlamtac and Michal Balog was essential for the conference's success. We sincerely appreciate their continued support and guidance.

The conference was held under the support of the Slovak research and development agency No APVV-19-0590.

An essential role in the preparation of the conference placed an excellent team of the organizing committee. Their hard work in organizing and supporting the conference was top-notch.

The success of the conference was supported by the signing of a cooperation agreement between the Department of Industrial Engineering and Informatics of the Faculty of Manufacturing Technologies with the seat in Prešov, Technical University in Košice, Slovakia, and The Institute of Information Technology of the Faculty of Computer Science, Information Technology and Energy, Riga Technical University, Latvia.

Close collaboration between the Technical University in Košice, Slovakia, with the National Technical University "Kharkiv Polytechnic Institute," Ukraine, and the Sumy State Institute, Ukraine, provided invaluable support in organizing the conference.

We would also like to thank Conference Manager Veronika Kissová, Angelina Iakovets, and Stella Hrehová, for their help and support with the conference preparation.

We strongly believe that the ARTEP conference provides a good ground for all researchers, developers, and practitioners to discuss all aspects of science. We firmly believe that the ARTEP 2024 conference technology is relevant to computerization, digitization, industry, and building solid partnerships. We also expect the next ARTEP 2025 conference to be as successful and stimulating as the contributions presented in this collection suggest.

Prešov, Slovakia

Michal Balog
Angelina Iakovets
Stella Hrehová
Khrystyna Berladir

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Michal Hatala	Department of Automotive and Manufacturing Technologies, Faculty of Manufacturing Technologies with the seat in Prešov, Technical University in Košice, Slovakia
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Anna Burduk	Department of Laser Technologies, Automation and Production Organization, Faculty of Mechanical Engineering, Wroclaw University of Science and Technology, Poland

Contents

Author Biographies

Michal Balog is head of the Department of Industrial Engineering and Informatics at the Faculty of Manufacturing Technologies with the seat in Prešov of Technical University in Košice. His publishing activities are introduced by more than 100 domestic and foreign publications. He is also a lecturer at local universities in Poland and the Czech Republic. Michal Balog is the organizer of many domestic and international conferences, is a tutor on PhD study programs, and has participated in numerous Slovak and international projects as a team member and as the project head. Among his most important project activities is the "Support and Expansion of the CVD Plus Transport Research Center" project from 2013 to 2020, where he was actively involved as a researcher. Associate Professor Dr. Michal Balog is a technical program committee member of more than 22 conferences from 2014 until now. He is a reviewer of many international articles. His research area focuses on information technologies, information systems management, and intelligent technologies in industry and transport.

Angelina Iakovets in 2014, has graduated from the Kherson National Technical University, where she received a master's degree in consolidated information analysis. In 2022, she graduated from the Technical University of Košice, where she received a PhD in industrial production management. Currently, she is a researcher at the Faculty of Manufacturing Technologies with a seat in Prešov of Technical University in Košice. She actively takes part in faculty projects and writes scientific articles. She has been the supervisor of more than 19 student theses. She actively cooperates with enterprises and ensures the cooperation of students within the framework of internship programs. Her research area focuses on using mobile applications and solutions, entrepreneurial information systems, manufacturing, and automation. She is a member of the EAI research group.

Stella Hrehová graduated from the Mechanical Engineering Faculty of the Technical University in Kosice. She received her doctorate in engineering technology from the Faculty of Manufacturing Technologies with a seat in Prešov, of the

Technical University in Košice in 2004. In 2011, she received the BSc in computer science from the P.J. Šafarik University in Košice. She has 25 years of teaching experience. Her scientific focus is on data processing, optimization, and augmented reality. She has published 14 books and more than 136 articles in scientific conferences and in journals. She is a member of the EAI research group.

Khrystyna Berladir graduated from Sumy State University in 2012, where she received a master's degree in Applied Materials Science. In 2017, she graduated from the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute," where she received a PhD. In 2023, she was awarded the academic title of Associate Professor at Sumy State University, where she currently continues as an Associate Professor of the Department of Applied Materials Science and Technology of Constructional Materials. In 2023, she was also a researcher at the Faculty of Manufacturing Technologies with the seat in Prešov of the Technical University of Košice. Dr. Berladir is the author of numerous publications in materials science and engineering, quality management, and engineering education. She is an editorial board member of *Journal of Engineering Sciences*, an organizing committee member of international scientific conferences, and an invited reviewer in influential scientific journals. She is a member of the EAI research group.

Part I
Engineering Education, Augmented Reality, 3D Printing

Chapter 1
Advantages of 3D Printing in the Education Process

Olha Kalman, Anastasiia Nazim, Ivan Pavlenko, and Vitalii Ivanov

1.1 Introduction

3D printing, unlike other manufacturing processes, being an additive process, has emerged as a viable technology to produce engineering components [1]. The aspects associated with 3D printing, such as less material wastage, ease of manufacturing, less human involvement, less post-processing, and energy efficiency, make the process sustainable for industrial use [2]. 3D printing was easily integrated into the concept of Industry 4.0 and 5.0 because it meets the main requirements of both concepts. 3D printing was one of the separate components of Industry 4.0 due to its special characteristics: modeling, simulating, programming, and printing. The complexity of such a production process helps provide an accurate manufacturing

O. Kalman (✉) · A. Nazim
Department of Industrial Engineering and Informatics, Faculty of Manufacturing Technologies with the seat in Prešov, Technical University of Košice, Prešov, Slovakia
e-mail: olha.kalman@tuke.sk

I. Pavlenko
Department of Industrial Engineering and Informatics of the Faculty of Manufacturing Technologies with the seat in Prešov, Technical University of Košice, Presov, Slovakia

Department of Computational Mechanics named after Volodymyr Martsynkovskyy, Faculty of Technical Systems and Energy Efficient Technologies, Sumy State University, Sumy, Ukraine

V. Ivanov
Department of Automotive and Manufacturing Technologies, Faculty of Manufacturing Technologies with the seat in Prešov, Technical University in Košice, Prešov, Slovakia

Department of Manufacturing Engineering, Machines and Tools, Faculty of Technical Systems and Energy Efficient Technologies, Sumy State University, Sumy, Ukraine

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process that will meet all customer demands. During the spread of the new concept of Industry 5.0, there arose the necessity of reducing waste production by the manufacturing process and also reducing the electricity consumption and other inputs for the manufacturing process [3].

3D printing is used in many branches, such as medicine, building, education, architecture, and manufacturing. Such a spread of 3D printing technology opens the opportunity to develop the process of preparing and managing such a process to provide the flexibility of such a technology and the flexibility to customers' demands.

1.2 Methodology of 3D Printing Process

Within 3D printing, essentially an additive manufacturing process, we create the foundational design of the part we intend to replicate [4].

In 3D printing, essential in an additive manufacturing process, the initial step involves crafting a foundational design of the desired part. This design is typically generated using computer software that interfaces with 3D printers. Subsequently, the software creates a specialized file format for the printer to interpret. When printing begins, the 3D printer reads this file and fabricates the product by methodically layering one stratum atop another. Nearly all 3D printing techniques rely on layering to construct a part [5]. These printers perceive components as a sequence of two-dimensional layers rather than a complete, solid piece. The operation of 3D printers, as illustrated in Figure 1.1, hinges on their ability to interpret the Standard Tessellation Language (STL) file format [6].

The core process of 3D printing to produce a three-dimensional object can be summarized as follows:

- *Design:* Initiate the process with the creation of the intended 3D object's design, typically generated using computer-aided design (CAD) software.
- *Digital Model:* Transform the design into a digital 3D model within the CAD software. This digital model represents the object virtually.

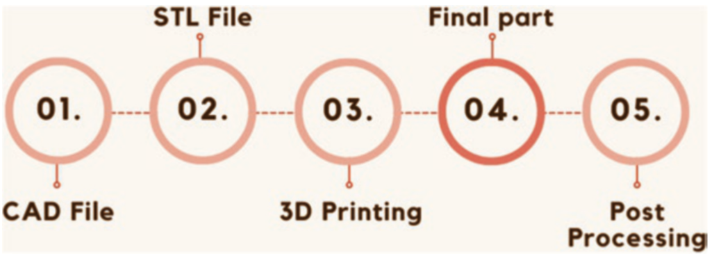

Fig. 1.1 The core process of 3D printing to produce a three-dimensional object

- *Slicing:* Utilize slicing software to break down the 3D model into thin, horizontal layers, effectively generating a 2D image of each layer. These sliced layers are usually saved in the STL format.
- *Printer Setup:* Prepare the 3D printer by ensuring its calibration and loading the appropriate printing material, which can range from plastic filament to metal, depending on the printer type.
- *Printing:* The 3D printer interprets the sliced model file and commences the printing process. The object is constructed layer by layer, employing distinct 3D printing technologies like Fused Deposition Modeling (FDM) or Stereolithography (SLA).
- *Cooling and Solidifying:* After depositing or curing each layer, the material is often cooled or solidified, preserving the intended shape.
- *Layer Bonding:* As printing advances, the layers are fused together, resulting in a cohesive 3D object.
- *Completion:* Upon concluding the printing process, the 3D object is typically removed from the build platform or printing bed.
- *Post-Processing (Optional):* Depending on the 3D printing technology and desired finishing, some objects may require additional steps such as sanding, painting, or assembly to attain the final product.
- *Quality Inspection:* Carefully examine the 3D-printed object for flaws or imperfections, and make necessary adjustments or corrections.

This is a simplified rendition of the basic 3D printing process, with variations depending on the type of 3D printer and materials in use. Expand the potential applications of 3D printed parts, with a focus on developing low-cost printer technologies and materials compatible with these printers [5].

1.3 Types of 3D Printing Technologies

Additive manufacturing (AM) and 3D printing are broad terms covering diverse techniques used to create 3D prototypes and structures from digital files [6].

In response to the demand for producing intricate models with exceptional resolution, various additive manufacturing (AM) techniques have been devised. These encompass different categories of 3D printing, such as those involving thermoplastic or polymer materials. The three leading 3D printing technologies for polymeric materials are stereolithography (SLA), fused filament fabrication (FFF), and selective laser sintering (SLS) [7].

SLA and SLS printers employ lasers to harden or fuse photopolymer resin and powder to produce objects. In contrast, FFF (fused filament fabrication) creates objects by extruding molten thermoplastics, which solidify rapidly.

It is important to note that various types of processes exist within 3D printing. These types are discussed in Fig. 1.2.

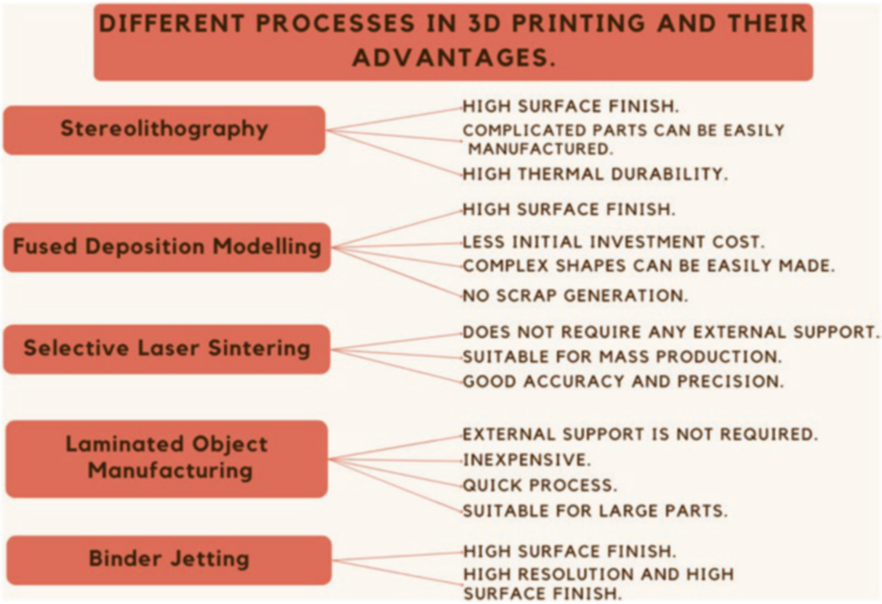

Fig. 1.2 Different processes in 3D printing

Each of the abovementioned processes is critical in achieving efficient product production and minimizing time and waste. These processes also facilitate the creation of complex structures with exceptional quality. The impact of 3D printing is transforming and modernizing various industries [8]. Fig. 1.3 provides a summary of diverse applications for 3D printing techniques.

The environmental characteristics of 3D printing, such as material waste reduction, post-processing requirements minimization, and cost-effectiveness, position it as a promising future technology. In addition, it offers sustainability benefits by enabling plastic reuse, recycling, and emissions reduction. The technology is also great for creating complex, optimized structures, resulting in lightweight parts with an improved strength-to-weight ratio. Consequently, adopting 3D printing contributes to developing environmentally friendly and resource-efficient designs [9].

1.4 3D Printing in Education Process

Considering the technical intricacies of 3D printing and the objectives defined by Industry 4.0, it is evident that 3D printing assumes a pivotal position within the structure of the Industry 4.0 framework [10].

3D printing brings forth many advantages that can significantly contribute to realizing Industry 4.0 objectives. These benefits encompass the capacity to seamlessly transfer digital data, oversee, and regulate the 3D printing process from a

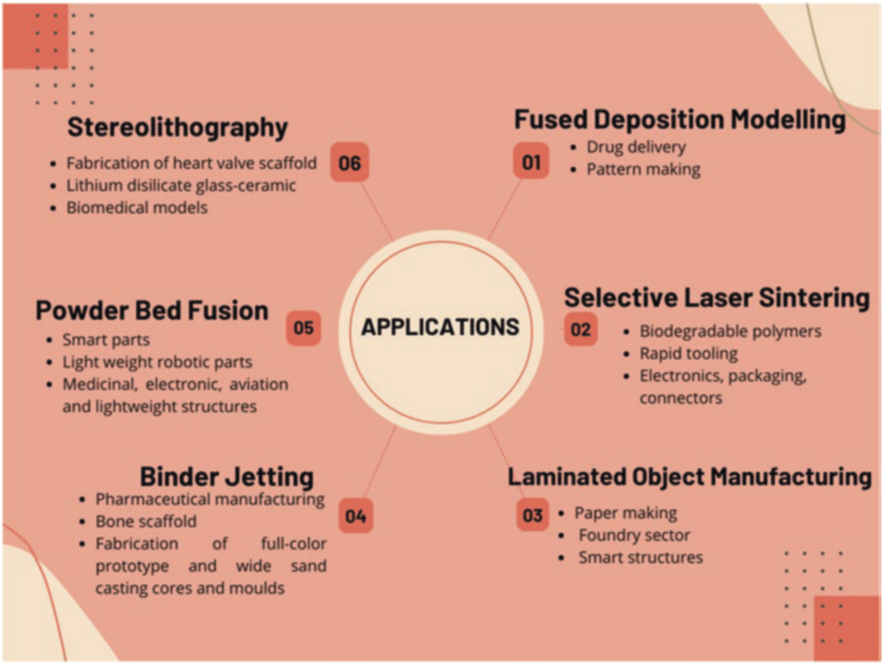

Fig. 1.3 Various applications of 3D printing processes

remote location, curtail the necessity for extensive human intervention, fabricate intricate and detailed geometries, harness smart materials, curbing waste generation, and diminishing post-processing demands [11].

The eco-friendly aspect of 3D printing has the potential to replace traditional manufacturing, offering cost-efficiency and environmental benefits by reducing ecological impacts. Each 3D printing technology has unique advantages and disadvantages, with 3D printed components often requiring minimal post-processing due to their ability to handle intricate geometries [12]. Of these methodologies, Fused Deposition Modeling (FDM) stands as the most prevalent, albeit most suitable for polymer materials [22]. On the other hand, powder-based techniques, like Selective Laser Sintering (SLS), encounter challenges encompassing the management of powders during handling, transportation, and storage [13].

In modern society, the widespread adoption of 3D printing is driven by its versatility and application in diverse industries. Beyond its technical uses, it is now acknowledged as a valuable educational tool that potentially transforms students' learning experiences [6]. By utilizing 3D printing to produce physical models, educators can adeptly communicate intricate concepts, particularly those requiring spatial reasoning, surpassing the capabilities of virtual and digital software. The ability to swiftly create customizable models facilitates interactive teaching methods, enhancing students' understanding of fundamental principles [14]. This pedagogical approach heightens student engagement and fosters a deeper comprehension of theoretical concepts while facilitating the integration of practical and theoretical knowledge and skills.

Even in the domain of mathematics, 3D printing proves its utility. Math students can harness this technology to fabricate tangible models of mathematical problems, thus enhancing their ability to comprehend complex concepts and stimulating active engagement with the subject matter [15]. The applications of 3D printing in education are extensive, spanning a broad spectrum of disciplines [16].

One area where it proves particularly useful is the provision of tangible 3D printed models that aid in visualizing and comprehending fundamental theories and concepts. This technology also empowers students to attain proficiency in advanced 3D design, swiftly generating prototypes of various objects and equipment commonly used in machining, manufacturing, maintenance, logistics, and operations [17]. This hands-on approach significantly enhances students' comprehension of how these tools function. Moreover, 3D printing offers ample opportunities for students across various subjects to interact dynamically and interactively with their learning material [16]. For instance, history students can breathe life into historical artifacts by printing replicas for in-depth study and analysis. Graphic design students can unleash their creativity by transforming their 2D designs into tangible 3D objects. Geography students can delve into the complexities of topography, demographics, and population distribution by creating 3D-printed maps [18]. In essence, 3D printing in education is a transformative tool that enriches students' understanding, creativity, and engagement across various disciplines. Its far-reaching applications offer students invaluable resources that foster a deeper appreciation and comprehension of their studies.

In the realm of science, 3D printing provides invaluable resources for students studying chemistry and biology. Chemistry students can craft precise 3D models of intricate molecules, yielding tangible representations of abstract concepts. Similarly, biology students can manufacture 3D models of cells, viruses, organs, and other biological structures, enabling a more comprehensive exploration of these intricate systems.

1.4.1 Advantages of Integrating 3D Printing in Education

Active Participation and Contribution: Students actively engage in every process phase, from initial study and design to the practical execution of objects. This not only generates excitement but also encourages active involvement and contribution.

Active Learning Environment: This approach ensures students are not passive recipients but are actively involved in creating objects related to the subject matter. Through hands-on experiences, students deepen their understanding and knowledge, fostering critical thinking, problem-solving, and creativity. It empowers students to play an active role in their learning journey, enhancing motivation and ownership.

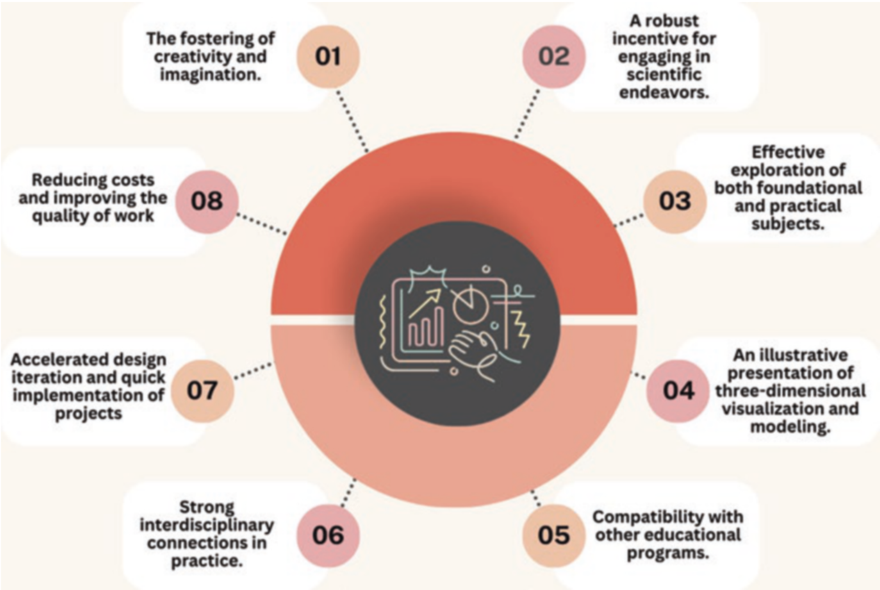

Fig. 1.4 Benefits of implementing 3D technology in education

Enhanced Knowledge Acquisition with 3D Visualization: Incorporating 3D visualization offers new avenues for knowledge acquisition. Visualizing objects in three dimensions allows students to understand better complex concepts, mainly those challenging to grasp through text or two-dimensional images alone. 3D visuals provide a richer dataset within a specific context, promoting improved understanding and facilitating deeper learning.

Development of Problem-Solving Abilities: The approach stimulates the growth of problem-solving skills. Students face real-world challenges in creating objects, strengthening their problem-solving aptitude. Through trial and error and repeated task execution, they become more confident in tackling intricate projects and concepts, ultimately enhancing their comprehensive understanding and knowledge.

More advantages of implementing 3D printing in the educational process are depicted in Fig. 1.4.

1.4.2 Practical Application of Industry 4.0 in the Education Sector

Demand for professionals in various industries is continually changing due to evolving methodologies and technology, notably in areas like 3D printing and Industry 4.0. Given the dynamic nature of the contemporary landscape, prioritizing the education and training of specialists in these fields is crucial, emphasizing practical competencies and immersive hands-on experience.

Integral to this is integrating Industry 4.0 technologies into BSc and MSc programs that are essential for adequately preparing students for the current market demands. By seamlessly combining curricula from these educational domains, future professionals can gain the necessary competencies and knowledge for proficiently utilizing and integrating Industry 4.0 technologies in production processes. This integration ensures that graduates are well-prepared for the evolving market and facilitates their growth into authorities and specialists within their respective domains, empowering them to leverage and apply the innovations of Industry 4.0 effectively.

In 2019, the Faculty of Manufacturing Technologies secured accreditation for two novel study programs, specifically "Smart Technologies in Industry" at the 1st-degree level and "Intelligent Technologies in Industry" at the 2nd-degree level of university studies. The primary objective underlying the establishment of these programs was to furnish graduates with the essential proficiencies and knowledge requisite for the effective implementation of digitalization methodologies and techniques across diverse domains of production and business, aligning with the tenets of the fourth industrial revolution. Enrolling in these study programs empowers students to cultivate the expertise necessary for applying state-of-the-art technologies to amplify and optimize processes within various industry sectors.

A graduate who has completed the "Smart Technologies in Industry" program is equipped with a diverse skill set that enables them to adeptly apply digitalization methodologies and techniques across a spectrum of industries and businesses, aligning with the fundamental tenets of the fourth industrial revolution, known as the Industry 4.0 concept. Possessing a comprehensive understanding of the subject matter, these graduates demonstrate proficiency in activities such as the formulation and management of technical documentation, the technical planning of production processes, and the acquisition of knowledge about production technologies, materials, manufacturing equipment, data collection and processing, digitization, as well as the oversight and administration of production workflows. Moreover, they are well-prepared to independently harness digital technologies within a professional setting, monitor and manage environmental factors, and actively contribute to environmental conservation while maintaining a steadfast commitment to workplace safety and health protocols.

An "Intelligent Technologies in Industry" graduate exhibits a profound mastery of the skills required to proficiently implement digitalization methodologies and techniques across a broad spectrum of industries and businesses, aligning seamlessly with the guiding principles of the fourth industrial revolution encapsulated in the Industry 4.0 concept.

Equipped with advanced knowledge, graduates from this program excel in designing intelligent production systems and optimizing their performance. They possess in-depth expertise in cutting-edge production technologies, materials, data acquisition, processing, and comprehensive management of production workflows. Additionally, industrial engineering graduates can lead transformative initiatives, integrating personnel, technologies, equipment, processes, information, materials, and energy throughout the product life cycle. They aim to establish a holistic system seamlessly incorporating artificial intelligence into operational activities for continuous development aligned with present and future organizational needs.

1.4.3 Laboratories Empowering Future Engineers

The Department of Industrial Engineering and Informatics is home to a range of dedicated laboratories (Fig. 1.5), primarily for conducting experimental investigations with a keen emphasis on enhancing managerial processes, particularly within the manufacturing domains. These state-of-the-art facilities provide students with invaluable practical experience and allow them to engage in experimental research under real-world conditions, directly aligning with the department's specific focus areas of their study programs.

Furthermore, these laboratories actively participate in an array of projects, whether they be on a domestic or international scale. According to the perspective of the department's faculty, modern and strategically oriented laboratories significantly enhance the appeal and efficacy of the educational process, contributing to a richer and more engaging learning experience [19].

1.4.4 Laboratory for 3D Printing

The Department of Industrial Engineering and Informatics has a specialized facility known as the Intelligent and Production Systems Laboratory. This laboratory serves a dual purpose: to facilitate the research endeavors of the department's academic staff and the practical learning experiences of its students.

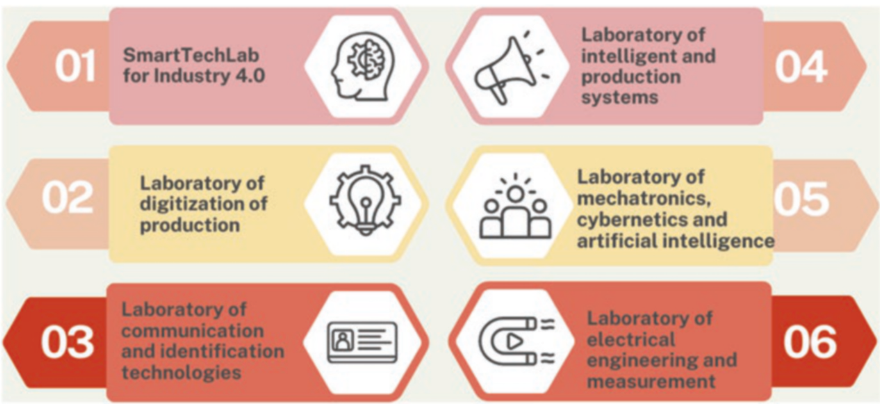

Fig. 1.5 Specialized laboratories at the Department of Industrial Engineering and Informatics

Fig. 1.6 The Intelligent and Production Systems Laboratory

The Intelligent and Production Systems Laboratory (Fig. 1.6) is an innovation hub where faculty members and students can engage in various activities. These encompass cutting-edge research and practical applications bridging the theoretical knowledge gap and real-world challenges. Here, the focus is on exploring the intricacies of 3D printing technologies, materials, and processes.

Through this facility, students are equipped with theoretical knowledge and gain invaluable practical insights into 3D printing. It is where ideas are transformed into tangible prototypes, experimentation meets application, and the principles of 3D printing come to life. The laboratory plays a pivotal role in enhancing the overall educational experience by offering a platform for students to apply their theoretical understanding, fostering their development as skilled professionals in this rapidly evolving field.

The Intelligent and Production Systems Laboratory boasts a substantial array of 3D printers, creating a robust environment where students can seamlessly translate their theoretical understanding into practical application. These 3D printers serve as instrumental tools for hands-on learning and experimentation, allowing students to immerse themselves in the dynamic realm of 3D printing.

In this laboratory, students have unrestricted access to diverse 3D printing technologies. They can harness these resources to give life to their ideas, fabricate intricate prototypes, and explore the intricacies of various printing materials and techniques. This practical exposure empowers students to bridge the gap between theoretical knowledge and real-world implementation, fostering their growth as adept professionals in 3D printing.

There are 3D printers in the laboratory, such as the following:

- Bambu Lab P1P (Fig. 1.7)
- Bambu Lab X1C
- FLSUN V400 Delta
- Elegoo Neptune 4 PRO (Fig. 1.8)
- SOVOL SV-04
- Creality CR-5 PRO HT