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Fraunhofer Institute for Factory Operation and Automation IFF

ENABLING KHARKIV-EDIH REPORT

Relevant Technology Scenarios for Digital Transformation Piloted with Kharkiv Producers

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Ihor Terekhov, Mayor of Kharkiv. Foto: Kharkiv City Council

Foreword

Message from the Mayor: »Driving Digital Transformation in Kharkiv«

The City of Kharkiv extends its gratitude to the project »Enabling Kharkiv EDIH« and the project »Digital Transformation of SMEs in EaP countries« financed by the German Federal Ministry for Economic Cooperation and Development (BMZ). These initiatives are of critical importance during this period of unprecedented challenges, as our city and region continue to endure the severe consequences of Russia's ongoing aggression against Ukraine. Their focused efforts in supporting digital transformation have provided much-needed guidance for our local businesses in these turbulent times.

The »Enabling Kharkiv EDIH« project has highlighted the transformative potential of digitalization in ensuring the resilience of Kharkiv's manufacturing companies. Faced with challenges such as labour shortages, disrupted logistics, and energy supply disturbances, digital transformation equips enterprises with the tools necessary to adapt and overcome. By embracing advanced technologies and modernizing their operations, our businesses are not only navigating current obstacles but also laying the foundation for sustainable growth.

We value the insights shared through the study on technology scenarios for the digital transformation of Kharkiv-based companies. The collaboration between Fraunhofer Institute for Factory Operation and Automation (IFF) and the National Aerospace University »KhAI« has resulted in a report that provides a roadmap for leveraging cutting-edge technologies to address the unique challenges faced by local industries.

The »Enabling Kharkiv EDIH« project and its preparatory activities have also set the stage for the conceptualization of the Eastern Ukraine European Digital Innovation Hub (Eastern Ukraine EDIH) initiative selected for funding by the European Commission. While the determination of Kharkiv-based companies to sustain operations and contribute to the city's economic recovery is truly inspiring, the Eastern Ukraine EDIH will capitalise on the achievements of the »Enabling Kharkiv EDIH« project to extend and amplify the impact of fostering digital transformation in key industries across the Eastern Ukraine.

The Eastern Ukraine EDIH will serve as an essential support system for local companies, providing access to advanced digital tools, expert consultations, tailored training programs, and multiple collaboration opportunities. Through this initiative, businesses in Eastern Ukraine will be empowered to adopt cutting-edge technologies, optimize their processes, and enhance their competitiveness in both local and international markets.

On behalf of the people of Kharkiv, I extend my deepest appreciation to Germany, German Federal Ministry for Economic Cooperation and Development (BMZ) and the »Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH« (GIZ), for continuous support of the Kharkiv region. Your solidarity and commitment to supporting our region demonstrate the profound impact of international collaboration in addressing global challenges. Together, we are laying the groundwork for a resilient, innovative, and prosperous Kharkiv.

Ihor Terekhov
Mayor of Kharkiv

1. Introduction

The use of digital technologies presents significant opportunities for Ukrainian public and private sectors, particularly during these challenging times. The ongoing Russian full-scale invasion in Ukraine has placed immense pressure on businesses, infrastructure and the economy in general, underscoring the need for resilience, adaptability and innovative solutions. Automated and semi-automated processes are key to enhancing efficiency, productivity and resilience. Modern and interconnected manufacturing facilities capable of providing real-time data can boost productivity and reduce downtime significantly, helping businesses navigate the complexities of the current situation.

The Eastern Ukraine European Digital Innovation Hub (EDIH), based in Kharkiv, is strategically designed to address these challenges. The war has severely impacted the region, causing significant destruction in key sectors, such as manufacturing, energy and agriculture. This disruption has also resulted in a massive displacement of the population, causing a shortage of skilled labor. The Eastern Ukraine EDIH aims to mitigate these effects by driving digital transformation across the region's industries, providing much-needed support to rebuild and modernize essential sectors and contributing to the region's postwar recovery.

Upon approval of the Enabling KHARKIV-EDIH project, the EDIH will officially commence its work in Ukraine on November 1, 2024, supported by the European Commission. This initiative will play a vital role in establishing connections with European partners as Ukraine joins a network of over 150 EDIHs, including 17 in Germany. This Digital Innovation Hub will support a wide range of industries and technologies relevant to both Ukrainian and European companies as well as public institutions, providing them with the tools to test new technologies, develop digital skills and access much-needed funding.

Within the GIZ funded Enabling Kharkiv EDIH project Fraunhofer Institute for Factory Operation and Automation (Fraunhofer IFF) together with National Aerospace University »KhAI« have been designing the Eastern Ukraine EDIH specifically to support the digital transformation of Eastern-Ukrainian manufacturing SMEs. Furthermore, Enabling Kharkiv EDIH project's activities implementing various knowledge-transfer initiatives to prepare the establishment of the Eastern Ukraine EDIH and to concretely provide essential support to Ukrainian SMEs to support their resilient, digitally advanced future.

The establishment of the Eastern Ukraine EDIH is not only a response to immediate needs but also a strategic move toward strengthening Ukraine's integration into the European digital economy. It aligns with national and regional development strategies, supporting key sectors, such as manufacturing, agriculture, energy and smart cities. The EDIH's focus on digital technologies, such as artificial intelligence (AI), cybersecurity, the Internet of Things (IoT), robotics and digital twins will empower local industries and public sector entities, enhancing their ability to adapt, recover and thrive in the current challenging situation and beyond.

This milestone marks a significant step toward enhancing the competitiveness of Ukrainian industries and underscores the importance of international collaboration in achieving sustainable growth and resilience. Through its work, the Eastern Ukraine EDIH will contribute to the broader goals of the Digital Europe Programme, the EU Digital Decade and the European Green Deal, while addressing the specific needs of a region severely affected by the war.

2. Scientific Approach

Kharkiv, historically a manufacturing hub in Ukraine, has been facing substantial challenges because of the war. The region, which contributes significantly to Ukraine's manufacturing output, especially in such sectors as machinery, aerospace and metalworking, has been severely impacted by damage to its infrastructure and workforce shortages. Despite these setbacks, Kharkiv remains a key player in the national economy, with a significant percentage of industrial companies expressing intent to transform digitally. The digital maturity of many companies remains relatively low, with limited integration of advanced technologies, such as IoT, robotics and AI. Kharkiv, however, displays great potential for recovery and growth by adopting innovative digital solutions, which are essential for rebuilding and modernizing the region's manufacturing sector.

A structured scientific approach was followed in the first phase of the Enabling Kharkiv EDIH project to assess the digitalization needs of Ukrainian manufacturing SMEs. The companies participating in this study – PLEXIWIRE LLC, UNISOFT Book Factory, BALEX Company Group, DB Aerocopter Ltd and TERRA LLC – represent key industries in Kharkiv's manufacturing ecosystem and reflect the broader challenges and opportunities faced by the region. By aligning technological solutions with these companies' specific needs, the project aims to demonstrate how digital advances can foster resilience and competitiveness in Kharkiv's postwar economy. These companies serve as prime examples of how the integration of digital technologies can address infrastructure limitations, improve operational efficiency and promote long-term economic stability in the region.

Initial Analysis and Workshop Methodology

The approach was based on three hybrid workshops with experts, designed to gather insights from various operational stakeholders across the manufacturing spectrum. These stakeholders came from management, operations management, work scheduling and other relevant units of the participating companies. The purpose of these workshops was twofold: to present potential technological solutions and to gain comprehensive understanding of Ukrainian companies' digitalization needs.

Various technologies, including ones developed by Fraunhofer IFF, were introduced at the workshops as representative examples of the broader, commercially available solutions, with the aim of demonstrating the capabilities to improve operational efficiency, quality and digital processes. Although specific solutions were highlighted, the technologies showcased are also available from other providers, allowing the companies flexibility in their choices. The potential implementation of these technologies can be well assessed by IFF experts in evaluating their impact, though it is not always fully quantifiable.

Workshop 1: Introduction and Needs Assessment

The first workshop served as an introduction to the Fraunhofer IFF and the participating companies. This session laid the groundwork for collaboration by highlighting Fraunhofer IFF's expertise in digital solutions and the technological capabilities available to support the digital transformation of manufacturing processes. Each company provided an overview of their operations, challenges, and strategic goals, setting the stage for identifying specific areas where digital technologies could drive improvements.

Workshop 2: Identifying Digitalization Needs

The second workshop focused on an in-depth needs assessment. Companies articulated their specific digitalization challenges and goals, ranging from manufacturing inefficiencies and outdated management processes to the need for advanced quality control systems and supply chain optimization. This workshop allowed the technical experts to map out the operational processes that stand to benefit most from digital transformation, such as assembly, maintenance, inventory management and educational content delivery.

Workshop 3: Technology Presentation and Alignment

In the third workshop, Fraunhofer IFF experts presented custom digital solutions that directly addressed the needs identified in the previous workshop. By aligning Fraunhofer's advanced technologies, such as digital twins, IoT integration, AI-driven predictive maintenance, VR and AR training modules and cobotics, with each company's specific requirements, the experts demonstrated how these solutions could be implemented to meet existing challenges and enhance operational efficiency.

Scientific Analysis and Knowledge Transfer

The workshops were structured to facilitate scientific analysis of knowledge transfer needs, ensuring that the solutions presented were not only technologically feasible but also practicable. This approach involved:

- Work and requirements analysis: A thorough analysis of current operational challenges was conducted, such as production quality issues, inefficient workflows and technology gaps. This analysis was crucial to pinpointing the exact areas where digital solutions could have the most significant impact.
- Stakeholder involvement: Various operational stakeholders from each company were involved to ensure comprehensive coverage of all areas affected by potential technology implementation. This inclusive approach facilitated a deeper understanding of the companies' needs and promoted buy-in from all relevant parties.
- Process improvement scenarios: Detailed scenarios for technology deployment were developed and customized to each company's unique operating contexts. These scenarios included adapted process descriptions, research on technology providers and recommended actions for successful implementation.

Outcome and Future Directions

This phase culminated in the development of a strategic road map for each company, outlining the next steps for implementing digital solutions. These road maps were designed to guide the companies through their digital transformation journeys, ensuring that they are equipped with the necessary tools and expertise to achieve their strategic objectives.

This project's scientific approach was instrumental in aligning technological capabilities with the specific needs of the Ukrainian manufacturing SMEs. Collaborative workshops and targeted knowledge transfer served as a strong foundation for the successful implementation of digital technologies, setting the stage for continued innovation and growth in the participating companies.

By continuing to work closely with the Ukrainian partners, the project aims to facilitate sustainable digital transformation that boosts competitiveness and drives long-term success in the manufacturing sector.

3. Ukrainian Companies' Requirements (Derived from the First Workshop)

In the second phase of the Kharkiv EDIH project, workshops were organized in which Ukrainian companies introduced themselves and articulated their digitalization needs. These sessions went beyond a simple study, providing a platform for companies to present their specific challenges and strategic goals, while also fostering dialogue on potential solutions. This methodical approach enabled us to gather in-depth insights into each company's unique operational requirements and digitalization aspirations. The following sections summarize the needs identified by the Ukrainian companies during their presentations, forming a solid foundation for the development of tailored digital solutions. These solutions aim to enhance not only the operational efficiency and competitiveness of the individual companies but also contribute to the broader goal of supporting the digital transformation of the Kharkiv region's industrial landscape.

3.1 DB Aerocopter Ltd

Founded in 1999, DB Aerocopter Ltd is a midsize company the aviation industry with approximately 250 employees. The company serves a diverse clientele, including government agencies, civil aviation companies and private buyers. DB Aerocopter Ltd specializes in the development and manufacture of helicopters and aircraft components. The company is currently facing challenges related to outdated management processes and a need for advanced assembly equipment. Their goals include enhancing manufacturing efficiency and improving management workflows. To this end, the company has expressed a specific desire to digitalize its management processes and modernize its assembly operations with advanced technologies.

Figure 1: DB Aerocopter Ltd

https://agentecomercialak1-3.blogspot.com

3.2 UNISOFT Book Factory

Established in 1994, UNISOFT Book Factory is a modern printing company based in Kharkiv, with over 350 employees. It serving diverse range of clients in the publishing and printing industry, including more than 200 publishers in Ukraine and Europe. UNISOFT Book Factory specializes in the production of books and other printed materials, including hardcover and softcover books, board books and premium packaging.

The company has made significant investments in modernizing its production capabilities, including over 1 million euros in equipment upgrades, and now holds a 25% market share in the Ukrainian printing industry. Despite these advances, UNISOFT Book Factory is still facing challenges, such as the need for more efficient production processes and additional integration of advanced printing technologies. Their strategic goals are focused on increasing production speed and improving quality, while simultaneously cutting costs.

To remain competitive in both domestic and international markets, UNISOFT Book Factory aims to digitalize its production management systems further and integrate advanced technologies, such as robotic systems and the Industrial Internet of Things (IIoT), in order to streamline processes and ensure long-term operational efficiency.

Figure 2: UNISOFT Book Factory

https://unisoft.ua

3.3 TERRA LLC

Founded in 1998, TERRA LLC is a midsize company specializing in the agriculture industry, with about 200 employees. The company serves a diverse range of clients, including large agribusinesses and small farms. TERRA LLC focuses on the processing and distribution of grain and other food products, ensuring high-quality output for both domestic and international markets. The company currently faces challenges such as outdated inventory management systems and a need for more advanced processing technologies. Their primary goals are to enhance

operational efficiency and improve product quality. TERRA LLC has shown a particular interest in digitalizing its inventory and supply chain management processes, as well as modernizing its production operations to incorporate advanced, automated solutions.

Figure 3:
TERRA LLC

https://terra.ua/en

3.4 PLEXIWIRE LLC

Founded in 2016, PLEXIWIRE LLC is a leading manufacturer of materials for 3D printing in Ukraine with approx. 50 employees. One of their key activities is the development and serial production of photopolymer resins for 3D printing. They are interested in expanding their research capabilities and are ready to collaborate in this area.

To date, they have two methods for creating new resins. The first method involves analyzing the properties of components and experimenting with mixing different ingredients to obtain resins with the required properties. The second method involves using experience from existing solutions. Both approaches involve research and experimentation, allowing PLEXIWIRE LLC to improve its products.

PLEXIWIRE LLC requires a solution that can effectively isolate UV resin components, opening up new opportunities for innovation. This approach would enable the collection of extensive data across various spectra, allowing for detailed comparison with existing material characterizations. By leveraging this data, PLEXIWIRE LLC aims to develop advanced systems capable of addressing complex engineering challenges and creating products that surpass current market alternatives.

PLEXIWIRE LLC continues to lead the industry by innovating and striving for excellence in 3D printing materials. It is ready for new challenges and collaborations to continue moving forward and developing its technology.

Figure 4:
PLEXIWIRE LLC

https://www.plexiwire.com/de/about-us

3.5 BALEX Company Group

BALEX Company Group is a midsize food manufacturing company with around 130 employees. The company specializes in the production and distribution of a wide range of food products, catering to both domestic and international markets. BALEX Company Group is currently facing challenges related to maturing production methods and a need for more advanced manufacturing technologies. The company's primary objectives are to enhance operational efficiency, streamline production workflows, and elevate the overall quality of their food products. BALEX Company Group aims to digitalize their project management processes and integrate advanced manufacturing techniques and equipment to boost their competitiveness. By implementing modern technologies, the company aims to enhance its market presence and ensure long-term business sustainability.

Figure 5:
BALEX Company Group

https://gmile.com.ua/en

4. Enabling Industry 4.0/5.0 Technologies, Solutions and Processes

The first workshop specifically focused on identifying the Ukrainian partners' needs and interests by poling the participating companies on the following topics:

- Digital assistance for manual tasks
- Technology-based knowledge transfer
- VR training
- Unmanned aerial vehicles
- Digitalization of material flow
- IIoT / AirBOX
- Image processing for quality inspection
- Digital twin for efficient manufacturing
- AI-Based image processing
- LIDAR - work area monitoring and crane assistance
- Hyperspectral imaging and analysis
- Feature-based identification of components
- Identification of plastics
- Service robots for inspection, cleaning and maintenance
- Safe human robot collaboration
- Multimodal human robot interaction and intuitive assistance
- Zero engineering robotics
- Fraunhofer IFF Elbfabrik

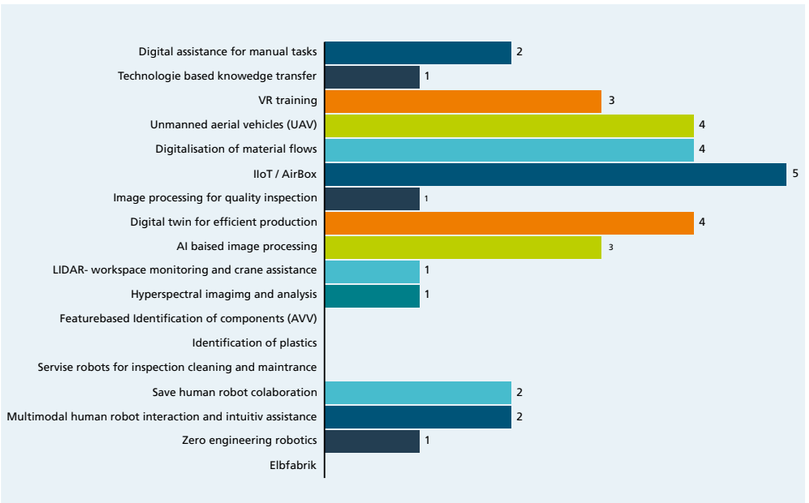

Figure 6: Poll results from Workshop 1 – Topics for Workshop 2

In the project's subsequent hybrid workshop, Fraunhofer IFF experts delivered presentations on the selected topics (bold), highlighting the institute's digital technologies, solutions and processes.

They additionally demonstrated how digital technologies can improve processes and outlined the operational actions necessary to implement these technologies effectively. The workshops culminated in the identification of critical operational processes, such as assembly or maintenance, that would benefit significantly from digitalization.

Building upon these insights, companyspecific formats were implemented, including bilateral workshops with companies such as PLEXIWIRE LCC and UNISOFT Book Factory. These formats facilitate knowledge transfer customized to the specific needs identified earlier.

4.1 Digital Twin for Efficient Production

The manufacturing sector is currently experiencing growing efficiency problems caused by short production cycles, high productivity demands and the desired high-capacity utilization of manufacturers. In addition, current production concepts struggle to keep up with the rapid and constantly increasing variety of models.

The asset administration shell, a digital twin for Industry 4.0, has been proposed as a solution to enable more efficient production. It uses administration shells that follow the entire life cycle of devices, machines and systems to represent assets (products and manufacturing resources). Plattform Industry 4.0 members Siemens AG, Daimler AG and Deutsche Telekom AG are involved in this initiative.

Figure 7: Presentation »Digital Twin for efficient Production« Workshop 2

The use of asset administration shells can increase efficiency by improving communication between different machines, devices and systems, enabling process optimization and bottleneck detection. It also facilitates flexibility and adaptability, enabling quick reactions to changing requirements or product configurations and modifications in manufacturing. Quality assurance is enhanced by monitoring the status of devices and systems in real time throughout their entire life cycle. Additionally, a digital platform improves communication and collaboration among the different parties throughout the life cycle via. This results in cost savings and shorter time-to-market through virtual planning, simulation and testing. Asset administration shells boost competitiveness, improve sustainability and make product life cycles more efficient.

More information

https://www.iff.fraunhofer.de/en/business-units/energy-systems-infrastructures/digital-twins-of-manufacturing-facilities.html

4.2 VR Training

Growing automation is changing humans' tasks and activities of in work systems. On the one hand, activities have an increasingly controlling and monitoring nature (Dregger et al. 2018) but also require rapid and competent human intervention in case of errors. On the other hand, learning opportunities to build up essential knowledge and experience are lacking, a phenomenon known as one of the ironies of automation (Bainbridge, 1983). Learning processes are consequently increasingly being transferred to virtual worlds. Rare, dangerous or difficult to access Learning situations can also be simulated. Standard immersive virtual reality (VR) training with interactive and realistic simulations is widely used for education and training purposes (Doerner et al., 2022).

The presentation provided insights into various virtual reality training solutions developed at Fraunhofer IFF and their uses. Among others, practical examples include digital solutions for work safety awareness and training (Fraunhofer IFF, 2024b), applications for problem-solving skills and scalable VR learning applications. The Technikmuseum Magdeburg scanned and brought old machines back to life in interactive visualizations (Fraunhofer IFF, 2024a), demonstrating the flexibility and scalability of VR training across different devices and learning environments, which are essential features of effective solutions (Scavarelli et al., 2021). (cf. Fig. 8)

Apart from presenting solutions, the presentation identified several key factors for successful VR training in which the Fraunhofer IFF has expertise. Its interdisciplinary teams enable Fraunhofer IFF to design effective learning applications that compile and transfer knowledge. Methodologically, they rely on immersive and self-determined learning, e.g., by integrating multimedia content into 3D models to enable self-paced learning. Furthermore, solutions can be customized to the target group's qualification level, desired output media and specific learning contexts.

Companies benefit from VR training solutions presented by using resources efficiently and avoiding manufacturing downtime since employees can learn processes unconstrained by time and place without causing real-world errors that incur costs. This is particularly useful for work safety trainings in industries, such as the chemical industry, machine operation, hazard prevention and safety inspections. VR training also helps address the skilled labor shortage by expediting learning and enabling new employees to acquire technical knowledge efficiently. It additionally makes training safe and sustainable, minimizing work accidents and retaining practical knowledge digitally. The innovative media used in the VR trainings at Fraunhofer IFF increase learning motivation and enable comprehensive understanding of key processes.

Enabling Industry 4.0/5.0 Technologies, Solutions and Processes

Figure 8: Scalable VR- learning application at the Technikmuseum Magdeburg, Workshop 2

More information

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4.3 Digital Assistance and Learning Systems

The main challenges currently being faced in the manufacturing sector are the wide range of product variants and a skilled labor shortage. These issues increase employees' workload and can ultimately have a significant impact on product quality.

Companies can introduce digital assistance systems in their manufacturing operations to address these challenges. Recommendations were made for successful organizational implementation. First, a thorough work and requirements analysis should be conducted to identify future users, the conditions required for the use of the new technology and the qualifications required of all employees to use this technology effectively. Participative methods are key to acceptance of new technologies among all employees affected by them. Additionally, plans for long-term use must be developed jointly to ensure sustainable implementation. Organizational integration is essential to embed new technologies in the existing operational structure. Occupational science holds that digital assistance systems ought to be designed to be learning-friendly and incorporate teaching methods, fostering better interaction between humans and technology.

Digital assistance systems are designed to provide information customized to the workers' needs and ergonomics so as to assist them and lighten their workload. Ideally, assistance information should be taken directly from existing CAD models, enabling high responsiveness to new variants or product changes. Assistive content may either be displayed on a monitor as augmented camera images or projected directly into the work area. Accurate representation of the contours of the components being assembled enables employees to assemble the components easily by following the contours displayed. When an assistance system is additionally equipped with sensors, the quality of the completed work can be verified. Critical work steps can be directly monitored and, if necessary, corrected. Upon successful inspection, users are notified that assembly is correct, the inspection result is documented and the system automatically advances to the next step.

The main benefits of Fraunhofer IFF's digital assistance and learning systems in manufacturing are to worker assistance during assembly, contextually aware and user-adaptive assistance information, reduced employee workloads, fewer assembly errors, expedited assembly and better product quality through targeted inspections.

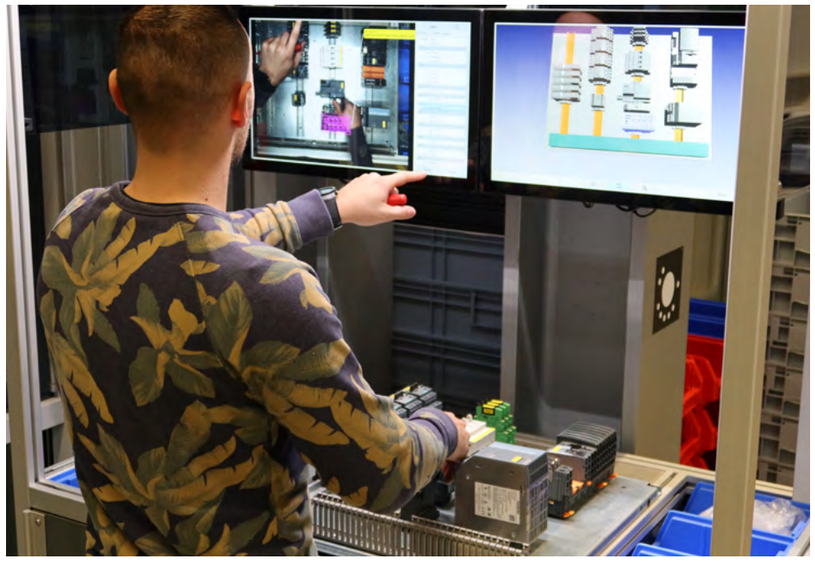

Figure 9:
Assistance and inspection system for the installation of control cabinets, Workshop 2

More information

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4.4 Digitalization of Material Flows

Modernizing material flow by digitalizing them is critical to achieving the vision of the smart factory of the future. This presentation by Fraunhofer IFF outlines the importance of integrating advanced technologies to enhance transparency and efficiency in logistics and manufacturing.

Digital twins play a key role by bridging the gap between the physical and the digital world. Real-time data collection from IoT devices enables continuous monitoring, predictive analytics and optimization of material flows. The aim is to provide accurate, timely and relevant information throughout the supply chain, from initial procurement preparation to final confirmation and invoicing. Comprehensive data integration ensures that decision-making is based on reliable information, improving responsiveness and operational efficiency.

The presentation stresses the importance of information logistics, focusing on delivering the right information at the right time and in the right quality. Digitalizing material flows makes it possible to supply data on every level of the process, facilitating seamless data transfer and integration. This ensures that all stakeholders have access to the information they need to optimize their operations.

IoT technologies are pivotal in this transformation. Passive and active IoT devices provide detailed tracking and condition monitoring of logistical items and equipment. Active IoT technologies in particular enable continuous data recording and transmission, supporting real-time process control and optimization. The integration of these technologies makes possible enhanced process transparency, anomaly detection and predictive maintenance.

Practical examples include RFID pallet tracking, which enables unique identification and life cycle management, and the use of IoT sensor boxes to monitor conveyor systems. These applications demonstrate the tangible benefits of digitalizing material flows, such as improved asset management, reduced downtime and enhanced operational efficiency.

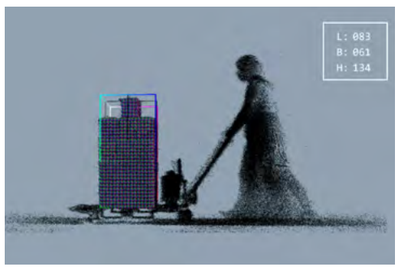

Figure 10:
Pallet scanning with 3D sensors, Workshop 2

The digitalization of material flows, supported by IoT technologies and digital twins, improves logistics and manufacturing processes significantly. By closing the digitalization gap, companies can achieve greater flexibility, transparency and efficiency, positioning themselves for success in the increasingly complex and competitive manufacturing landscape (cf. Fraunhofer IFF 2024).

More information

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4.5 Human-Robot Collaboration and Interaction

Robotic systems that palletize print products are a significant advance in automation and efficiency in productive environments. This presentation by Fraunhofer IFF outlines various robotic solutions and their impact on palletization.

Unchained Robotics' MalocherBot is a versatile solution adaptable to a wide range of product types and sizes. Despite its slower speed than conventional palletizers and the increased maintenance because of more frequent movement, its adaptability and the availability of spare parts make it a valuable asset in diverse productive settings. The system, which costs around €125,000, achieves a throughput of 12 units per minute.

Another solution is a row palletizer, designed for higher throughput through parallel operations and precise pallet stacking. However, its specialized parts require specific maintenance, and it demands a considerable footprint and an incoming feed arranged in a row for optimal efficiency. This system, which costs around €200,000, achieves a throughput of 4 cycles per minute.

The Pile Palletizer, similar in cost to a row palletizer, enhances pallet stability with a brickwall pattern. It provides higher throughput through parallel operations but also requires specialized maintenance and a significant footprint. Efficient operation depends on incoming feed arranged in piles, achieving a throughput of 6 cycles per minute.

All in all, the integration of these robotic systems into palletization yields several benefits, including improved handling flexibility, enhanced stability and greater autonomy through advanced robot vision and sensing capabilities. Challenges, such as space availability, material flow, safety considerations in shared work areas and maintenance requirements, must be addressed, though, to fully realize the benefits of these technologies.

The digitalization and automation of print product palletization by robotic systems substantially improve efficiency and flexibility. Although they require a significant initial investment and regular maintenance, these technologies position companies to handle diverse product types and sizes better, ultimately enhancing productivity and operational effectiveness.

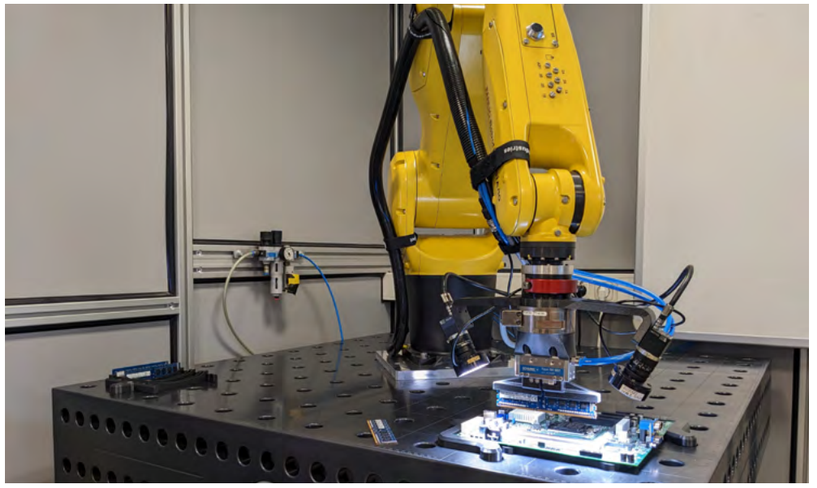

Figure 11:
IFF use-case lab, Workshop 2

More information

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4.6 IIoT / Airbox

The smart factory of the future is a vision of a highly flexible and adaptable productive environment with full transparency throughout the value chain. This vision entails the integration of digital twins at all levels, enabling real-time monitoring, analysis and optimization of production systems. Current market trends underscore the importance of digital twins in capturing real-time data from sensors and IoT devices to enhance predictive analytics and simulation capabilities. These technologies enable remote operations, advanced decision-making and seamless integration into AI and edge computing.

Distributed data acquisition systems, such as the AirBOX, are crucial to addressing the complex processes of advanced manufacturing. The AirBOX, capable to connect to a set of over 50 different sensors (plug and sense principle) and to also connect to any classic industrial sensor (with additional integration efforts) facilitates the monitoring of values such as environmental conditions, presence and localization. Its connectivity through standard interfaces and data protocols ensures quick data analysis and visualization on IoT platforms. AirBOX applications include real-time process monitoring, anomaly detection and improving process transparency.

Internal test and demonstration applications, such as air quality, humidity, noise and acceleration monitoring in specific areas, showcase the AirBOX's capabilities. It supports predictive maintenance and enhances operational efficiency by supplying direct and indirect data. Additionally, in various industrial use cases the AirBOX was integrated in measurement setups such as precision sensors and camera-based alignment in assembly processes for quality assurance and documentation.

AirBOX's distributed data acquisition and intelligent monitoring capabilities exemplify the future of smart factories. The combination of real-time data acquisition with advanced analytics enables companies to achieve higher precision, reduce errors and improve process efficiency, resulting in better product quality and operational performance.

Figure 12: Distributed data acquisition with the AirBOX, Workshop 2

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4.7 Unmanned Aerial Vehicles

The AutoDrone UA project, focused on the detection and identification of explosive ordnance (EO) in challenging terrains, represents a significant advance in the field of autonomous drone technology. Spearheaded by experts from Fraunhofer IFF, Kharkiv Aviation Institute and Tauber Geo-Consult, the project aims to address the critical issue of land mines and unexploded ordnance, which pose a deadly threat even in peacetime.

The project leverages 3D Lidar-based predictive flight control to ensure accurate and safe flights under poor visibility and GNSS conditions enabling systematic flights over rough terrains at low altitudes. The drones can be equipped with various sensors, such as a magnetometer survey kit, Magdrone R4 3.0, for precise EO detection. With this sensor equipment, the automated UAV flight system can accurately detect ferromagnetic materials, ensuring efficient area scans with 1-2 cm accuracy.

First flight tests demonstrated the system's capability, albeit further optimizations are needed to reduce jerking, increase speed and improve battery management. Ongoing real tests are intended to enhance the latency and synchronization of measurement data, ensuring high-precision flight planning and execution for high-quality measurement data at constant low altitudes and high speeds.

Automated drone flights have clear advantages over standard ground-guided movements: smoother control of magnetometer sensor motion, higher scanning speeds and fewer artifacts. This state-of-the-art approach is far more accurate and faster than manual methods.

The project is also exploring various sensors that detect non-magnetic EO, including thermal cameras, ground-penetrating radar (GPR) and multi- and hyperspectral cameras. These technologies enable the detection of different EO types, from plastic anti-personnel mines to artillery ammunition, enhancing the system's versatility and effectiveness.

One of the project's highlights is the development of a resilient drone swarm network, capable of high-level secured flight control, advanced obstacle avoidance and reliable EO detection. This innovative approach allows for automatic planning and precision control of swarm missions, ensuring robust and efficient EO detection.

Figure 13: AutoDrone flight test, Workshop 2

More information

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4.8 AI Image Processing

The increasing complexity of modern manufacturing and inspection processes necessitates the use of advanced technologies such as AI image processing. This presentation highlighted several applications in which AI techniques significantly enhance inspection and quality control tasks.

One example focused on the inspection of turbine center frame modules, a critical component of jet engines. The manual assembly of these modules is challenging because of the large number of variants. AI-based segmentation and simulation are employed to automate optical inspection to detect missing or misplaced parts. Assembly errors are detected by comparing real-time images with simulated CAD models, reducing the reliance on manual inspection and improving overall accuracy.

Another application involves the automated quality control of truck trailer signs. The task entails checking the location, color and presence of logos, letters and signs under varying light conditions and from different perspectives. AI-driven text and object detection strategies combined with image normalization techniques ensure precise inspection, even under challenging conditions. This automated system detects errors early, facilitating prompt corrective actions and enhancing the quality control process.

The third example addressed the intelligent disassembly of electronic devices for recycling, part of the iDeaR project. This process involves automated, nondestructive disassembly using robotic systems. AI image processing tasks include the identification and assessment of components and fasteners. Challenges, such as occluded screws and varying light conditions, are managed by advanced object detection and classification techniques, ensuring efficient and accurate disassembly.

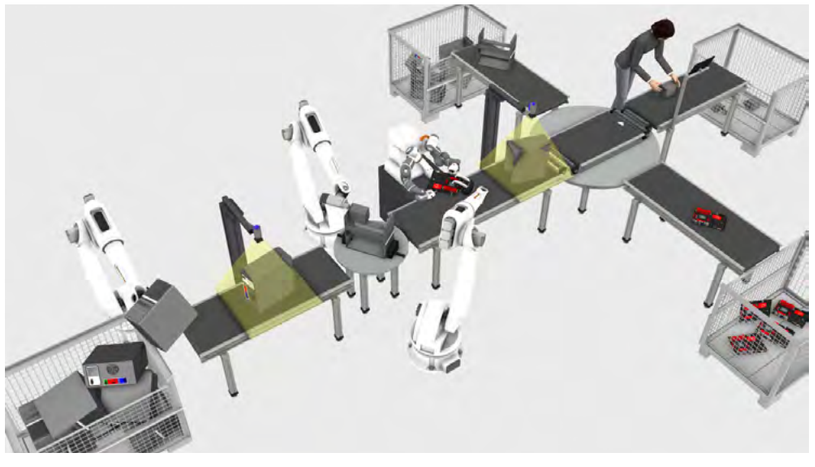

Figure 14: Intelligent Disassembly of Electronics for Remanufacturing and Recycling, Workshop 2

These examples demonstrate AI image processing's transformative impact in various industrial applications. By automating complex inspection and disassembly tasks, these technologies not only improve accuracy and efficiency but also contribute to sustainable practices and enhanced product quality (cf. 11).

5. Selected Application Examples

5.1 PLEXIWIRE LLC USE CASE

PLEXIWIRE LLC, specialized in 3D printing filament production, is currently facing significant chal- lenges to improve the transparency of their manufacturing processes and to ensure consis-tent product quality. To address these topics, PLEXIWIRE LLC could benefit from implementing a digital twin of the production and launching an IIoT network to trace the production status and product parameters. Connected data acquisition systems, such as the AirBOX system of Fraunhofer IFF, would enable the company to track filament properties, production parameters and warehouse details in real-time. Such systems could help to identify production issues and detect product anomalies.

Following the digitalization process, the introduction of AI-driven analytics or predictive maintenance systems could be a next step to further enhance operational efficiency and make use of the data acquired in the production environment. Automated data analysis instead of manual observation of machines and products can create totally new insights.

By adopting advanced digital technologies, PLEXIWIRE LLC could embark on follow-up projects to further increase the digitalization status of their production and benefit from the data availability, such as implementing advanced analytics for process optimization and exploring additional IoT applications for supply chain management, ultimately boosting operational efficiency and maintaining a competitive edge.

5.2 UNISOFT Book Factory

UNISOFT Book Factory, specialized in the production of books and printed materials, is aiming to implement additional digital technologies to its operations to support existing solutions like digital logistics or digital resource planning. To achieve this goal, UNISOFT Book Factory could benefit from acquiring data from machines automatically instead of reading information locally on screens installed at the machines. Intelligent software to collect and analyze the data could enable the company to get a more comprehensive understanding of the information delivered from the machines.

In addition to these, robotic systems customized for the printing industry could make physical work much easier because large volumes of paper need to be loaded into the machines. The MalocherBot, for example, could automate palletizing while adapting to different product types and sizes which allows for reducing the physical efforts of the employees. Although slower than conventional palletizers, this system is flexible and easy to maintain, making it ideal for dynamic printing environments such as UNISOFT's. Solutions, such as a row palletizer or pile palletizer, could alternatively be implemented for higher throughput, ensuring precise stacking and stable palletizing of a range of print products.

The company aspires to implement a print-on-demand service to optimize resource efficiency. However, the requisite software infrastructure, an appropriate online platform, and the digitalization of these operational processes are currently absent.

These technologies could increase production speed, streamline operations and improve overall output. Future projects could include upgrading these solutions to cover additional stages of the production process, such as packaging and logistics, while focusing on integrating robotics for handling and transportation, further enhancing operational efficiency and competitiveness.

5.3 BALEX Group Company

BALEX Company Group has already achieved a strong status in automation and data recording. The company aims to enhance the analysis and visualization of its existing data. A key focus lies in developing advanced methods to interpret the collected information and provide actionable insights. This would enable the organization to derive greater value from its digital resources and support data-driven decision-making processes.

Another strategic goal for the company is the intelligent derivation of process metrics from digital data. By leveraging these metrics, the company seeks to facilitate rapid and informed decision-making. The ability to extract meaningful indicators from operational data will further strengthen the efficiency and responsiveness of their processes.

In addition, BALEX Company Group sees potential applications for AR in onboarding new employees at various machine locations, even in the absence of on-site experts. Remote guidance through AR solutions could effectively support training and reduce dependency on physical presence. Moreover, the company aims to further digitize business processes, both internally and in customer relations, including the implementation of electronic document workflows and improved forecasting for production planning.

6. Conclusion and Next Steps

In close collaboration with Ukrainian manufacturing SMEs, Fraunhofer IFF will describe one technology deployment scenario, which includes a modified process description, research on technology providers and a description of actions for potential implementation.

The Enabling Kharkiv EDIH project has successfully demonstrated how a solid foundation for advancing digital transformation could be created in the Ukrainian companies involved: PLEXIWIRE LLC, UNISOFT Book Factory, BALEX Company Group, DB Aerocopter Ltd, and TERRA LLC. Through targeted efforts and the application of advanced technologies, notable progress has been made in addressing the specific challenges these companies face, identifying potentials for improving their operational efficiency, product quality, and overall competitiveness. After assessing the potential benefits of various technologies, the next steps for the companies may involve exploring ways to gradually integrate these solutions into their production processes.

The project highlighted the transformative capability of digital technologies in modern industrial applications. PLEXIWIRE LLC, a company specializing in 3D printing filaments and UV resins for 3D printing processes, can benefit from introducing AI-driven analytics and new maintenance approaches. The use of automated data analysis instead of manual observation routines can enhance operational efficiency by anticipating equipment failures, ensuring continuous production and minimizing downtime.

PLEXIWIRE LLC is considering the introduction of advanced analytics and additional IoT applications to potentially improve supply chain management and enhance overall operational efficiency. Furthermore, the development of AI-driven quality control systems is being evaluated as a future step to help ensure consistent product standards and increase reliability.

UNISOFT Book Factory identified potential improvements through implementing robotic systems that will reduce the physical strain on employees. The company could also benefit from implementing IIoT solutions to optimize production processes. Machines will display operational data locally on their screens, enabling employees to manually verify and input the information into a unified table.

Future projects for UNISOFT Book Factory could focus on digital logistics. The development of software or a web-based platform utilizing ‘print-on-demand’ technology could enable the companie’s digital department to process and print products based on remote user orders without the need for direct communication.

BALEX Company Group can benefit from improved evaluation and display of existing data. In addition, the intelligent derivation of key process figures from digital data is relevant in order to support employees in decision-making processes. AR solutions can support the training of new employees on existing machines at a wide variety of locations, even if there are no experts on site and remote training is required. They also want to further digitalize their business processes (internally and in customer relations), e. g. through electronic document flow and forecast for production planning.

BALEX Company Group plans to explore the integration of AI driven quality control systems, expand the use of IoT for predictive maintenance and enhance its use of robotic solutions to further automate production processes. The aim is to gradually develop a more connected and efficient food processing environment that enhances productivity and supports sustainable growth. Additionally, BALEX Company Group may consider further research into the application of digital twin technology across various aspects of their operations to identify potential opportunities for improved efficiency and cost savings.

DB Aerocopter Ltd, an established company in the aviation industry, aims to digitalize its administrative processes and automate assembly operations using advanced technologies. The integration of digital assistance systems and model-based assembly inspection is expected to help DB Aerocopter Ltd streamline management workflows and enhance production efficiency, supporting the company’s objectives of improving operational performance and product quality.

The focus for DB Aerocopter Ltd will be on expanding its process automation and enhancing assembly operations with advanced technologies. This will include exploring diverse automation solutions and AI applications to streamline operations and therefore increase product production efficiency and expanding sales opportunities.

Specialized in food processing, TERRA LLC expressed strong interest in combining all business processes by implementing a digital Enterprise Resource Planning System (ERP) system. The implementation of IoT solutions and advanced manufacturing technologies will enable the enterprise to optimize and eventually automate its manual processes. The implementation of carefully selected technologies tailored TERRA LLC’s specific needs has the potential to significantly enhance operational efficiency and improve product quality.

TERRA LLC will continue to integrate advanced IoT solutions and explore new manufacturing technologies to optimize their e. g. inventory and supply chain management processes. These efforts will facilitate real-time monitoring, predictive maintenance and operational efficiency.

Future Collaboration and Support

Collaboration with European und Ukraine technology partners and experts will be essential for Eastern Ukraine European Digital Innovation Hub (EDIH) and its targeted Eastern-Ukraine manufacturing SMEs. Involving these partners will provide Ukrainian businesses access to advanced technological solutions and the expertise needed to drive their digital transformation, while facilitating accession to the European Union and reconstruction in Ukraine during and after the war.

The GIZ funded Enabling Kharkiv EDIH project has demonstrated the potential impact of digital technologies on industrial processes and provided a clear road map for future advances. By leveraging the innovative solutions provided by Fraunhofer IFF and National Aerospace University»Kharkiv Aviation Institute”, PLEXIWIRE LLC, UNISOFT Book Factory, BALEX Company Group, DB Aerocopter Ltd and TERRA LLC will be well-positioned to achieve sustained growth, enhanced competitiveness and continued operational excellence.

As one of these key technology partners, Fraunhofer IFF and National Aerospace University »Kharkiv Aviation Institute« have already demonstrated their ability to provide solutions that meet the companies ‘needs. This collaboration highlights the broader importance of fostering ongoing partnerships with technology providers across Europe to navigate the complexities of digitalization effectively and unlock its full potential.

In order to continue advancing digital transformation in Ukraine, it is essential that the German government and other countries and international bodies maintain and increase their support.

7. Publisher's Information

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