Connectivity & Communication

Research Group TEC | Manufacturing Technology

White Paper

TECHNISCHE UNIVERSITÄT DARMSTADT

PTW TU DARMSTADT

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1. The Cluster Connectivity and Communication within the TEC research group

1.1. What does the cluster Connectivity and Communication stand for?

The cluster Connectivity & Communication develops the information and communication technologies (ICT) for the networked and data-driven production of tomorrow. This includes the consideration of hardware as well as software and addresses IT security issues. Fundamental approaches in computer science and electrical engineering are efficiently implemented in industry-related application fields of production and findings are derived in the form of recommendations for action for science and industry. These are transferred to tutorials and industry working groups.

The data obtained from manufacturing processes in real time must be transmitted by smart components for processing and storage. By implementing uniform and open interfaces as well as protocols based on international standards, secure communication is enabled both between plants and in networks. The standards of communication will be transferred to new application areas of production and furthermore participate in the transfer of experience from protocol application to industry.

The scientific work in the cluster relates on the one hand to the development of system architectures and on the other hand to the development of research methods for the systematic analysis and evaluation of ICT for production. In this course, benchmarks are created and examined based on objective evaluation criteria that need to be defined. To this end, the cluster uses PTW's TEC Lab as a living lab for application-oriented research and develops demonstrators for validation and know-how transfer in collaboration with the other clusters in the TEC research group.

1.2. Research group TEC

Since the beginning of 2021, we have jointly formed the research group TEC | Manufacturing Technology within the Institute for Production Management, Technology and Machine Tools (PTW) at Darmstadt University of Technology. Our vision is to conduct trend-setting research for data-driven, adaptable manufacturing technologies in resource-efficient, responsive production. Enthusiasm for our research, a high level of commitment and initiative, as well as openness and curiosity in breaking new ground are essential characteristics of our TEC team.

The TEC research group has grown together from the three former research groups *Additive Manufacturing*, *Machine Tools and Industrial Robots*, and *Machining Technology*. Thus, we are able to cover a broad field of manufacturing technology. Shortly after the changeover, the closer cooperation in the TEC research group became apparent through simpler communication, as well as more agile project application and processing. In order to address specific topics, the research clusters *Smart Components*, *Advanced Modeling*, *Connectivity & Communication* and *Monitoring & Control* were established in the TEC research group. However, these clusters do not represent strictly delimited groups, but are rather to be understood as open spaces for exchange among the colleagues. This enables a differentiated view of the topics from different directions and ensures a targeted exchange of experience and knowledge.

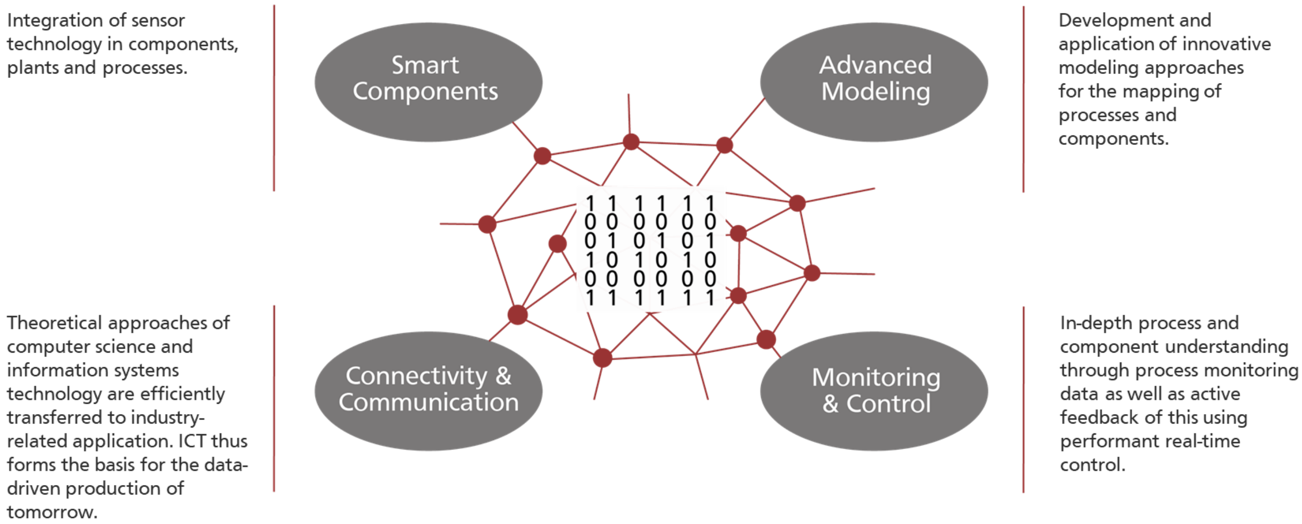

Figure 1: Expertise of the clusters within the TEC research group

With the TEC-Lab, PTW has a technical center with a climate-stable measurement and sample preparation room as well as modern machinery. It provides the perfect environment to quickly develop and test new approaches for data-driven manufacturing using agile methods in a solution-oriented manner. With various demonstrators for data-driven manufacturing technologies and networked production solutions, the fun and enthusiasm for data-driven production is also awakened among young scientists.

Figure 2: TEC-Lab at PTW

2. The importance of end-to-end connectivity and communication for the production of the future

2.1. Vision

The vision of the research cluster is shaped by current developments in the IT and industry sectors. In the long term, the cluster is developing the target image of a European production giganet. This is shaped by the following developments:

- Merging of Operation Technology (OT) and Information Technology (IT): In the view of the automation pyramid, the levels integrate into a common IT infrastructure. This results in special requirements for the IT security of networks and IT devices.

- Dissolution of the automation pyramid into a networked, continuous service-based value creation network within the company. The networking between companies is becoming a value creation ecosystem. This offers potential for more intensive supplier-customer interactions, creates new digital marketplaces and promotes the ability to react to unknown problems and disruptive influences.
- Industrial data spaces for specific industries with the same requirements and interfaces to bring value creation closer together and establish secure data infrastructures that comply with EU law. Plattform Industrie 4.0 is striving for a Data Space Industrie 4.0. Federal architectures and decentralised open-source-based IT technologies are key to complying with European legislation on data protection and achieving digital sovereignty. The International Data Spaces Association (IDSA) proposes a reference architecture model for secured cross-enterprise data exchanges.[1] Gaia-X is a European initiative to build a common data infrastructure consisting of an infrastructure ecosystem linked to a data ecosystem via federation services to ensure secure, EU-compliant exchange of data and services.[2]
- Building and merging new architectures such as RAMI4.0, RAM-IDS and Gaia-X. The architectures link vertical levels of Industrie 4.0 across the entire product life cycle, e.g. RAMI4.0, and horizontally enable cross-industry information exchanges, e.g. RAM-IDS.
- Merging the Internet-of-Things (IoT)[3] with the Web-of-Things (WoT)[4]: The IoT provides technologies for finding and addressing devices on the Internet. In the industrial environment, the devices are often equipped with sensors, are part of a machine or system control and provide data for further processing. The WoT serves to locate and address devices as well as information and data of virtual representations on the internet. The WoT thus provides fundamental elements for the architecture of Gaia-X.
- The digital twin as a virtual representation of product and production entities and service-based approaches as essential elements of cyber-physical production systems (CPPS) but also of data and software components - collectively referred to as assets: The Industrial Digital Twin Association (IDTA) as a user organisation of VDMA, ZVEI, Bitkom and companies is striving for a digital twin in which all information on the characteristics and behaviour of an asset in the Industrie 4.0 domain is stored. According to the IDTA, this will be designed as an asset administration shell (AAS) that maps the life cycle of the assets as a whole.[5]
- Developments on the OPC UA Companion Specifications and Asset Administration Shell: The Cluster Connectivity & Communication will follow the developments of the standards and demonstrate the utility value and possible applications for manufacturing within the framework of demonstrators in a Living Lab.
- Industry 2030 vision of the Plattform Industrie 4.0[6]: The mission statement represents the target image of Industry 4.0 in the year 2030. It is characterised by the three pillars of sovereignty, interoperability and sustainability (see Figure 3). They embody the basic principles to be technically designed for the development of digitally networked value creation ecosystems.

[1] https://internationaldataspaces.org/

[2] https://www.gaia-x.eu/

[3] With reference to the application in industrial environments, the term "Industrial Internet of Things" is used. Here, however, the Internet of Things is used because of the similarity in terminology to the Web of Things.

[4] https://www.w3.org/WoT/

[5] https://industrialdigitaltwin.org/technologie

[6] https://www.plattform-i40.de/IP/Redaktion/DE/Downloads/Publikation/Leitbild-2030-f%C3%BCr-Industrie-4.0.pdf?__blob=publicationFile&v=11

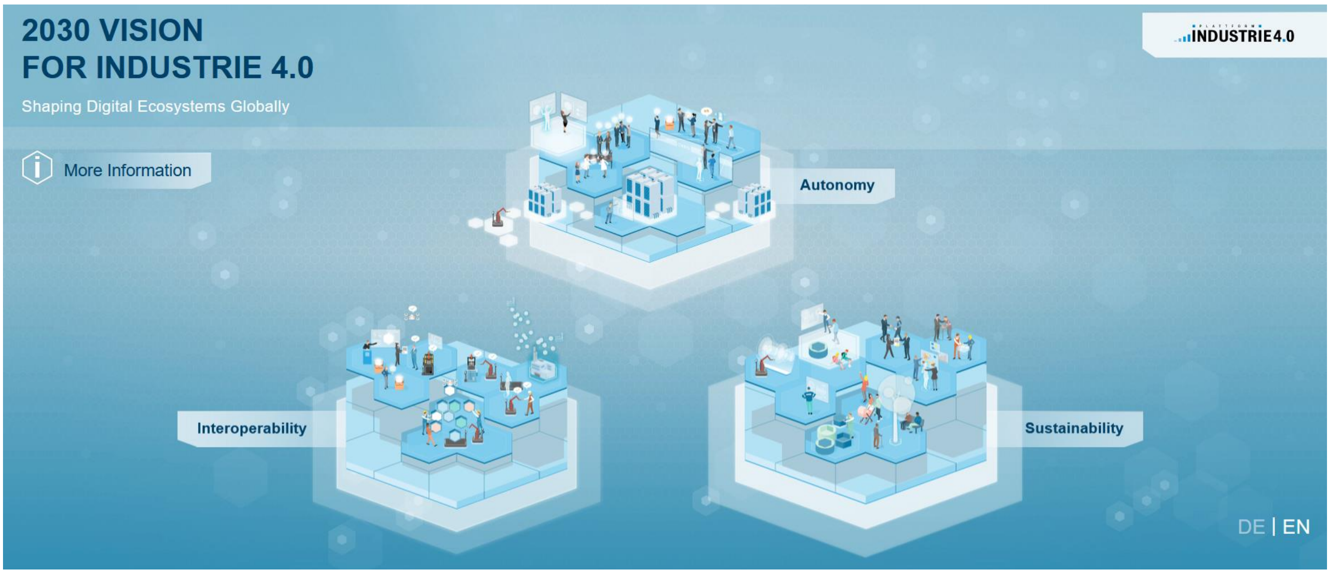

Figure 3: 2030 Vision for Industrie 4.0[7]

The Connectivity & Communication research cluster defines its vision on these trend topics with a focus on the networking and interaction of manufacturing equipment, such as machine tools, industrial robots, sensor-integrated components, tools and clamping devices as well as measuring equipment, such as tool setting devices, coordinate measuring machines and optical measuring instruments.

The cluster Connectivity & Communication will act as an innovation driver for the other three research clusters in the TEC research group and thus support novel technologies in the areas of Smart Components, Advanced Modelling and Monitoring & Control in their research and development and ensure the interoperability of the technologies. To this end, the cluster aims to achieve a high level of data availability at PTW and will enable the continuous use of data along the vertical integration and demonstrate this in research projects in cooperation with the other three clusters. For this purpose, own services will be developed and made available to industry under an open source licence and explained in open access publications. Corresponding software components will be made available via open source projects, e.g. via GitHub or GitLab. The aim is for industry to benefit from the cluster's research activities at an early stage and to stimulate further developments at the institute.

2.2. Requirements for Connectivity & Communication in the Production Environment

The requirements for communication solutions in the production environment are diverse and strongly dependent on the application and its value proposition. The requirements are:

- IT security, e.g. according to ISO/IEC 27001 international standard for information security management systems (ISMS), security measures such as firewall, encryption, trusted cloud services, monitoring, etc.
- Planning and design based on "security-by-design" approaches with access control, configurable usage rights
- Compliance with the General Data Protection Regulation (DSGVO) in handling personal data
- Anonymisation of information with possible personal reference
- Compliance with the Machinery Directive 2006/42/EC
- Maintainability
- Robustness against external and internal disturbances
- High transmission rates
- Real-time capability in the near machine environment depending on the application
- Scalability

[7] https://www.plattform-i40.de/PI40/Navigation/DE/Industrie40/Leitbild2030/leitbild-2030.html

- High degree of standardisation for interfaces, data formats, protocols in the phases of the data value chain
- Reliability in data processing and storage
- Quality standards and certifications for data stocks

2.3. Use Cases

The projects in section 3 provide insights into the concrete technical implementation and point to the demonstrators that can be shown at the Living Lab of PTW in the long term.

- Establishment and operation of a data-continuous vertical and horizontal integration for the acquisition, processing, display, storage and transmission of data and instantiation of digital services as software functionalities.
- Reduction of reaction times from anomaly detection to the time of maintenance and servicing through immediate data processing, characteristic value formation and communication to an MES and ERP system.
- Communication between machines and plant, e.g. for displaying and controlling the transfer of sister tools in a common virtual tool magazine.
- Creation of cloud-based secure long-term data storage for increasing the availability of data for training machine learning models.
- Human-machine interaction with interfaces to sensory and cognitive assistance systems, e.g. for AI-supported operation of machine tools via newly designed, interactive user interfaces using natural language processing and augmented reality and virtual reality technologies.

3. Projects and offers to the industry

3.1.1. EuProGigant

EuProGigant is a research project supported by an Austrian-German project consortium to build a cross-location, digitally networked production ecosystem. This ecosystem demonstrates how added value for customers and manufacturing companies can be practically implemented through increased value creation based on the smart and sovereign use of data. The "European Production Giganet for calamity-reducing self-orchestration of value creation and learning ecosystems" (EuProGigant) is the first funded industrial project with practical implementation of Gaia-X principles and aims to illustrate the technological and economic benefits of the open, European multi-cloud Gaia-X infrastructure. The project will demonstrate how highly networked production can be equipped with self-organising and stabilising properties (see Figure 4). Thanks to sovereign data and information exchange between different edge and cloud computing nodes within a common data ecosystem, sustainable and resilient production becomes a reality.[8]

[8] https://euprogigant.com/

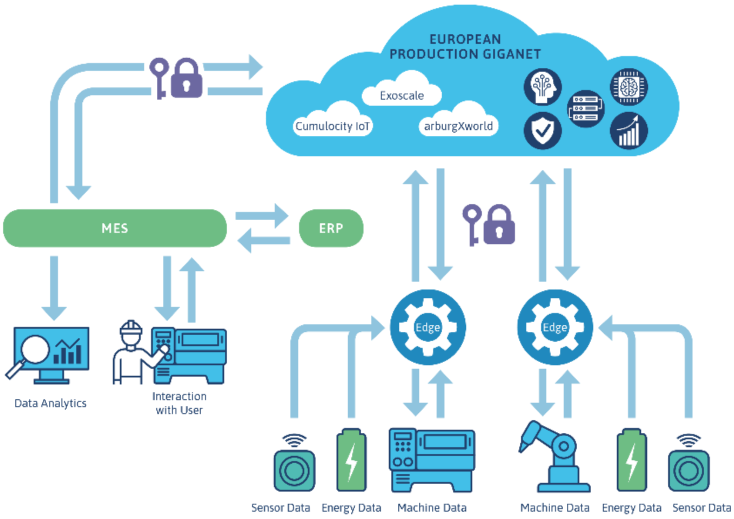

Figure 4: Vertical integration in the EuProGiant project

3.1.2. Pay-Per-Stress

The aim in the Pay-per-Stress project is the development and prototypical implementation of a load-oriented payment model for use with machine tools. The dependence of the leasing rate on the load of the machine has the potential to make the leasing of complex machines more efficient and fair. For this purpose, knowledge of the actual stress on the machine and its components is taken into account on the one hand, and an understanding of the cause-effect relationship between machine stress and wear on the other. The stress factor developed from these serves as a monetary evaluation unit for the pay-per-stress approach and as a basis for the further development of existing business models towards intelligent service offerings. In addition to evaluating the required data based on artificial intelligence, blockchain technology is used for legally compliant data exchange (see Figure 5). The project is based on a blockchain technology called Hyperledger Fabric.

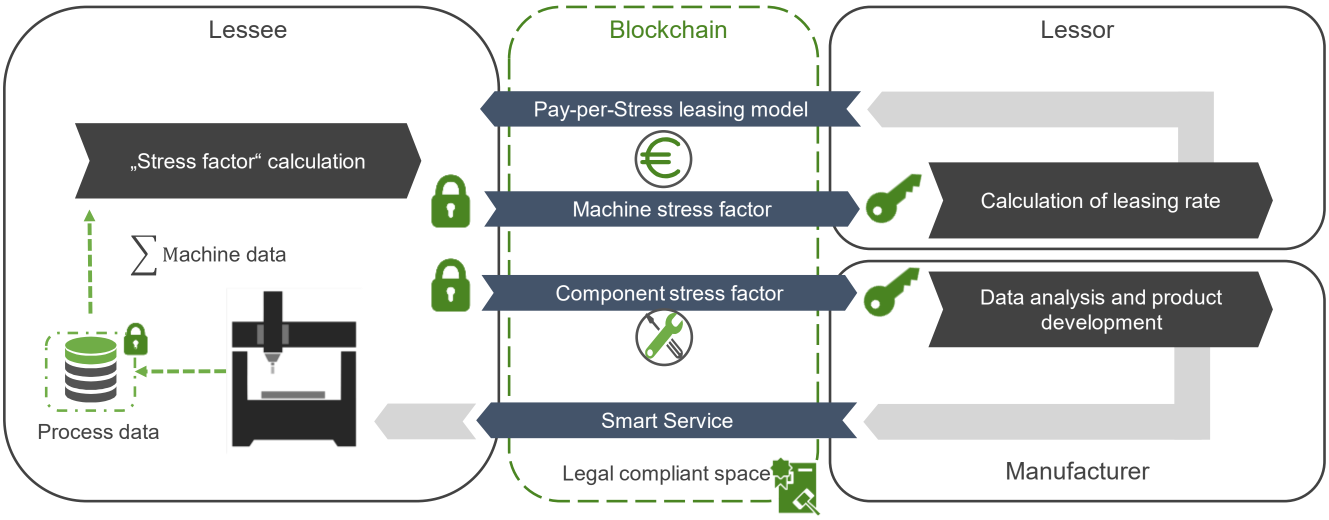

Figure 5: Concept for the implementation of pay-per-stress

This allows the decentralised execution of software components and data storage. This ensures data integrity. In addition, Hyperledger Fabric protects data confidentiality through identification and access rights management. So-called smart contracts as digital, software-based contracts are used decentrally via blockchain technology and authentication to create transparency regarding processing steps between provider and customer in the blockchain and to enable payment transactions.[9]

3.1.3. Plattform dataPro

Almost all sectors and companies in the manufacturing industry in Hessen are confronted daily with the dynamic developments of digitalisation in the production environment and their issues in connecting to modern IT infrastructures as well as the feasibility of new, digital business models (see Figure 6). Small and medium-sized enterprises (SMEs) in particular are often overwhelmed when it comes to following and implementing developments in the field of digitalisation, as they usually do not have the necessary know-how in-house.

The project Plattform dataPro will show companies how they can benefit from the developments in the field of digitalisation and which possibilities are already available for their company today.

The aim of the dataPro platform project is to create a digital and physical environment that is unique in Germany for the transfer of knowledge of research results and development trends in the future field of data-driven production. Based on the production of a customised product on standard industrial manufacturing machines, innovations in data-driven production, based on the triad of service, platform and process, can be efficiently experienced by visitors and workshop participants in a form established at PTW and DiK.[10]

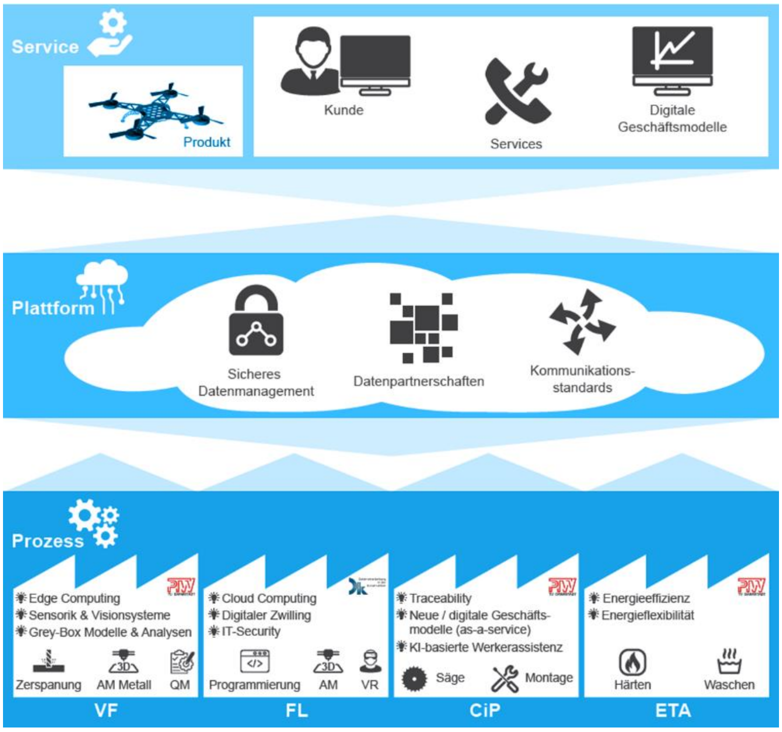

Figure 6: Interlocking the triad of service, platform and process.

3.1.4. DiNaPro

Digitization creates new opportunities and potential for promoting sustainable development. A wide variety of data sources provide a multitude of data, for example time series data from production, CAD data from construction, but also measurement data from quality control. Until now, the use of the full

[9] https://pay-per-stress.de/

[10] https://plattform-datapro.de/

potential of this information has often failed due to the central availability at the companies and across the entire value chain, as well as the linking of these data. Therefore, the focus of the research project "Model-based digitalization of sustainable production networks along the product life cycle" (DiNaPro) is the development of the integral digital twin as the central data object. It presents thus a uniform data model and data exchange format and builds the for the optimization of ecological sustainability. The integral digital twin is enriched with data from the entire product life cycle (see Figure 7).

The integral digital twin is enriched with data over the entire product life cycle, which is made available to users in the form of data-driven assistance systems. For example, CO2 emissions can be monitored live during production or sustainable operational optimization can be carried out by means of CO2 adaptive process planning.
The implementation of the developed project contents takes place at the learning factories of the institutes PTW and DiK of the TU Darmstadt as well as in the industry. The project is supported by a strong consortium of development partners and industrial companies. This ensures the transfer of the results.

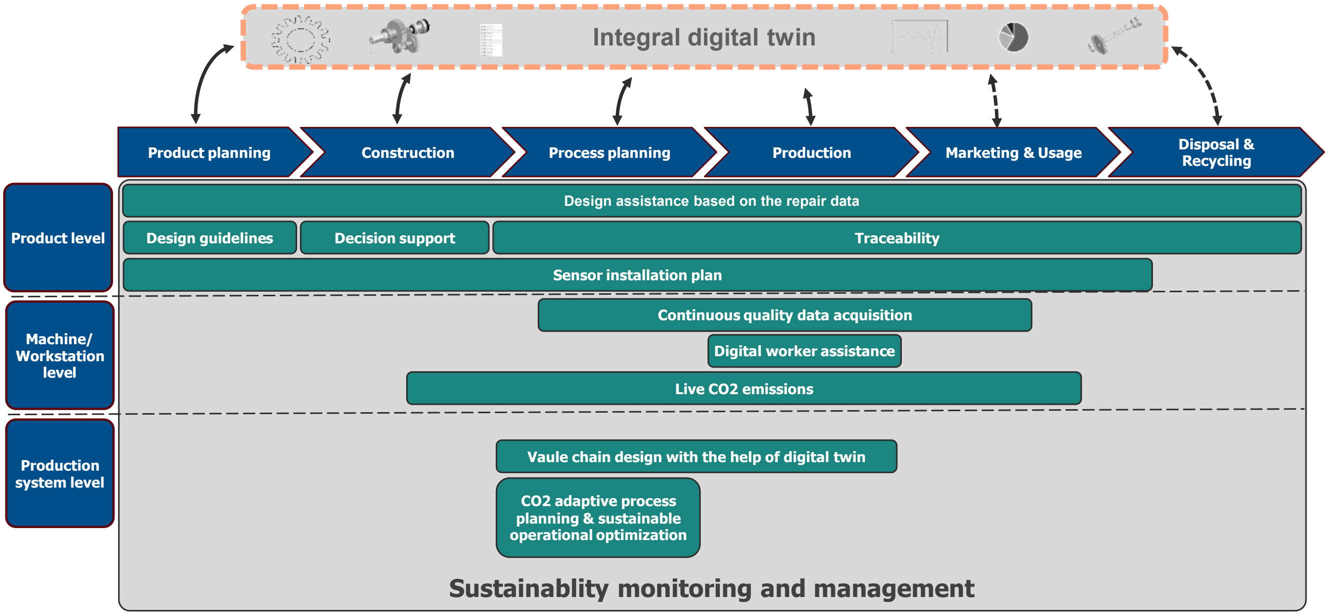

Figure 7: The integral digital twin at the center of the product lifecycle

3.2. Service offers

In the dataPro platform project, training offers related to the listed trend topics are currently being developed so that they are available to industry. In addition, the TEC research group develops consulting and development services on request with and for the industry.

4. Dissemination of knowledge

In addition to events for students and industry partners, we implement the knowledge gained in demonstrators that serve to reinforce knowledge and provide training and further education. In the Connectivity & Communication cluster, there are several demonstrators that are intended to address the target group of industry on the one hand and students of mechanical engineering, mechanics, mechatronics and computer science on the other. The demonstrators are intended to demonstrate the connection and networking of machines in production as well as the use of edge and cloud computing for the smart use of data for production and can be experienced in minimal examples in the TEC Lab. The basis for the demonstrators and their continuous further development is provided by the use cases considered in the research projects.

5. List of publications

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