MORGEN DENKER MAGAZINE

Fraunhofer IESE

The journal for fans of the digital future

Focus on the Digital Twin: Sustainable, resilient and safe into the future

The Director of Fraunhofer IESE, Prof. Dr. Peter Liggesmeyer, sees the Digital Twin as a key technology for the German economy.

Dear readers,

The concept of Digital Twins, which originated at NASA in the late 1960s, is increasingly finding its way into our professional and private lives today. Simply put, they are digital representations of real objects or networked systems and bridge the gap between the physical and digital worlds. However, Digital Twins are always created with a goal or business case in mind. These can, for example, be building service-based business models or developing new sources of value creation.

One of the main areas of application is Industry 4.0. Digital representations can be used, for example, to test and optimize products as early as the design phase – even complete production systems can be maintained with the help of the Digital Twin in order to avoid downtimes. The areas of application go much further, how-ever, if we consider, for example, the support of medical diagnostics using the Digital Patient Twin. Doctors can simulate therapeutic measures and the effects on the patient's body and organs. This provides them with valuable information for further treatment.

In addition to Digital Twins in the areas of production and healthcare, at Fraunhofer IESE we are also intensively working on the potential of Digital Twins in the Smart City. It is about more than just the digitalization of buildings and streets, because cities are complex dynamic systems in which the optimization of energy supply or mobility, for example, plays a major role. And how environmentally friendly would it be if the streetlights only lit up when vehicles or pedestrians were approaching or if we were guided directly to the nearest available parking space in our Smart City?

With these reasons and with concrete improvement goals in mind, Fraunhofer IESE has been researching on the Digital Twin technology for many years already. We also offer solutions for various application areas – for the benefit of the economy and society as well as for a sustainable, resilient and safe future. Find out more in the first issue of our MORGEN DENKER magazine!

Enjoy reading!

Yours

Peter Liggesmeyer

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A Digital Twin is the virtual representation of systems and processes. It enables virtual tests, shortens development times and thus the time to market for new products. The IESE experts design Digital Twins specifically according to the wishes of their business customers. In this interview, Frank Schnicke explains how the Eclipse BaSyx solution is used.

What are the advantages of Eclipse BaSyx?

The idea behind the Industry 4.0 middleware Eclipse BaSyx is to enable the fast and, above all, cost-effective implementation of standardized Digital Twins – also known as Asset Administration Shell – and their infrastructure. And not just in terms of function, i.e. whether the Digital Twin does what it is supposed to do, but also in terms of non-functional aspects. For example: Is it not only secure but also scalabe? We are not talking about several thousand or hundreds of thousands of Digital Twins of individual companies, but we are quickly talking about three-digit millions, if not billions. These figures show the amount of data and Digital Twins that are generated.

In which sectors is BaSyx used?

The main focus of our work with Eclipse BaSyx is clearly production. However, we are also using BaSyx in many other areas, such as Smart City, Smart Grids and Digital Healthcare. In the research projects we carry out here at IESE, we have found that the challenges with Digital Twins are more or less always the same. First of all, I need an infrastructure that – as I mentioned – is securely scalable. Next, I need information about the asset – regardless of the domain.

What makes the solution stand out from the competition?

A major added value of Eclipse BaSyx is that it is open source. This means that anyone who uses it is authorized to make their own modifications. We at Fraunhofer IESE are of course very happy to support companies in this. However, if a company builds something together with us and then wants to make minor modifications afterwards, these adaptations can be carried out independently. Another important advantage is that you can participate in the further development of the solution. We are constantly updating the software, as are our partners. This means that all users have free access to the latest version of the open source software – without having to invest anything.

How does the process work with customers?

In principle, the question at the beginning of a project is always: Where does the customer stand? In other words, have you already determined where the challenges lie, or do you just have a vague feeling that things are not running smoothly? If this is still unclear, we first hold workshops in which we work out the company's vision – i.e. where the journey with the Digital Twin should take us.

But what is also very important is: what are the intermediate steps and the "low hanging fruit"? In my experience, the implementation of Industry 4.0 is often approached as a big-bang migration. This means that you have an ambitious goal, but it is difficult to achieve. We put great emphasis on taking initial measures that contribute to this ambitious goal, but at the same time guarantee a return on investment at a very early stage.

What is an exemplary use case?

A typical use case of our work is breaking up of data silos. Nowadays, a lot of data exists in data silos. This means that you always have the same data point, but in different repositories. The interesting question now is: How do I deal with this? The Digital Twin can help by introducing standardized interfaces that break down these data silos and create a central point of contact. If the Digital Twin is also standardized, we can also

achieve simplified communication. For example, I buy a new milling machine and then – instead of a gigantic pile of paper – I receive a Digital Twin that presents all the data in an interoperable format, i.e. can be integrated into my own IT systems.

How does Fraunhofer IESE implement the Digital Twin in companies?

Once the right use case has been identified, there are various ways in which we proceed. Typically, we support the customer in enabling them to set up the infrastructure for the Digital Twin. We model relevant data in the Asset Administration Shell – always with a view to the latest research results, of course. We then integrate the Digital Twins into applications, such as dashboards or similar, to make the added value visible.

Are there any specific project examples?

We had a very illustrative project with a company that coats textiles. You have to imagine the process like this: Large rolls of fabric run through machines. A powder is applied, which is then heated with burners. This dyes the fabric. This was a manual process that required many individual work steps by several employees. We carried out a retrofitting together with the company.

This means that we have installed sensors that determine whether the burners are still doing what they are supposed to. We have collected the data in Digital Twins of the machines and displayed it visually in a dashboard. The production manager can now easily see from his office whether the process is still running properly. In contrast to the past, when he still had to walk to the machine, open a flap and look inside the machine. The Digital Twin really makes work easier!

"We put high focus on selecting and implementing the initial measures that contribute to the ambitious goal but still guarantee an early return on invest."

Frank Schnicke
Department Head
Digital Twin Engineering

PODCAST TIP

DEEP DIVE

Digital Twins for SMEs – quick and easy to use (German version)

BaSyx lays the foundation for Industry 4.0

Industry 4.0 is the digitalization of production. It integrates processes, devices, employees, products and all other relevant assets into a standardized digital system. Industry 4.0 thus enables connectivity, holistic data analysis, a better understanding of production systems and revolutionary approaches to production systems. Eclipse BaSyx implements the technical basis for Industry 4.0.

BaSyx is an open-source middleware for Industry 4.0 that is based on the Asset Administration Shell and enables the digitalization of production. Eclipse BaSyx was developed by Fraunhofer IESE and numerous other partners back in 2016 as part of the BaSys 4.0 research project and has been continuously developed since then. Eclipse BaSyx now also enables small and medium-sized companies to create standardized Digital Twins along their production processes.

Efficient production even with batch size 1

The production processes are highly automated and therefore very efficient for large batch sizes. However, the markets are demanding more and more flexibility. Traditional automation architectures require a great deal of effort to change the programming and introduce new products. Eclipse BaSyx supports service-based manufacturing architectures that create each product on the basis of individual recipes. The middleware provides the necessary software components to realize batch size 1 production today.

End-to-end digitization makes production processes transparent

Production processes are complex and sometimes difficult to understand. Questions such as the following are often inadequately answered: How efficient is the existing equipment? Where are the bottlenecks? Why are there quality problems? The answers require a thorough understanding of the production processes.

A lot of data is already available today. However, this data is often encapsulated and stored in machines that communicate using proprietary protocols. The Asset Administration Shell introduces a standardized interface to the assets and enables the creation of Digital Twins that support the analysis of manufacturing processes and process analysis. Digital Twins also score highly in terms of sustainability and offer companies the opportunity to create meaningful reporting for their carbon footprint.

"Together with Fraunhofer IESE, we are working on the use of Digital Twins based on a high-performance IT infrastructure."

Jürgen Hamm
Lead Architect
NetApp Twin Solution

The digitalization of production needs a suitable Infrastructure

For larger companies in particular, around a billion Digital Twins can easily be created in the course of digitizing production. A powerful infrastructure is needed for handling them, as Jürgen Hamm, Lead Architect NetApp Twin Solution, explains: "Together with Fraunhofer IESE, we have been working for years on future-proof solutions for the use of Digital Twins based on a high-performance IT infrastructure. In order to develop suitable application."

Further information:
https://eclipse.dev/basyx/

The Digital Twin goes green

The manufacturing industry is one of the largest emitters of CO_2 emissions and accounts for around 31% of primary energy requirements. According to a Bitkom study, up to 12.7 million tonnes of CO_2 could be saved in industrial production if digitalization were accelerated. To exploit this potential, Fraunhofer IESE leading the research in the "greenProd" project on energy-optimized production.

The vision of the greenProd research project is to promote the transformation of the manufacturing industry and maximize the use of renewable energy. The aim is to achieve this by reducing the use of fossil fuels in order to reduce greenhouse gas emissions on the one hand and lower energy costs in companies in order to increase their competitiveness on the other.

Digital energy twins as a basis

To achieve these goals, the project partners are developing green digital energy twins. These green digital energy twins comprise Asset Administration Shells that enable the representation of production steps, products and interfaces as well as the availability of renewable energy. They record emissions that occur and allocate them, describe the energy consumption of certain steps and the CO_2 footprint of the energy mix and provide predictions about the availability of renewable energy. This enables comprehensive tracking of the CO_2 footprint across all production steps, which promotes measurability and comparability. For example, customers can compare different products with each other or manufacturers can carry out optimizations.

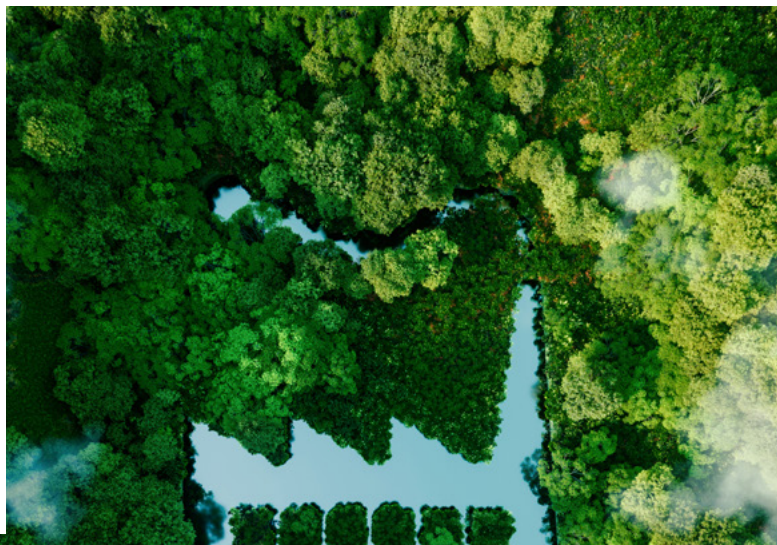
Exploiting optimization potential

The collected data offers the opportunity to make decisions in order to optimize the production process. One starting point for this is the consideration of the energy share in the production chain when making investment decisions, to better integrate efficiency criteria. Another option is to adjust the production speed, taking into account production capacity utilization and delivery deadlines. For example, a pump application could be set so that the pump runs at a constant speed in the more efficient operating range. It would also be possible to adjust the production speed of machines to ensure efficient operation. The effects of this can then be read off the data in the green digital energy twins.

Energy-efficient planning

Another optimization option is to plan the production process. Various production steps have to be carried out in a factory hall, whereby not all machines are used to capacity at all times and not every process requires the same amount of energy. The CO_2 footprint can be reduced by carrying out energy-intensive processes during phases of high availability of renewable energy. This also leads to a cost advantage, as electricity prices tend to be lower at this time. Companies with flexible electricity tariffs or that buy their own electricity on the exchange can benefit from this.

The greenProd project shows how the use of Digital Twins can promote energy-efficient production and thus make products significantly more sustainable. And those who produce in an environmentally friendly and efficient manner will remain competitive in the future.



The digital product passport

The ticket to sustainable circular economy

Nowadays, environmental protection and sustainability are important values that influence our consumer behavior in many ways. The digital product passport is an innovative idea that has the potential to fundamentally change the way we interact with products. Thanks to the digital product passport, consumers can make conscious decisions and choose products that correspond to their values and needs. At the same time, it opens up new opportunities for companies to communicate their sustainability efforts transparently and strengthen customer trust. This gives them the opportunity to develop digital business models and rethink their own value chain. With the Industry 4.0 tool Eclipse BaSyx, the digital product passport can be implemented for companies in all sectors.

The digital product passport is part of an EU-wide package of measures to promote the circular economy. It not only contains information about where the product comes from, but also about its exact composition and how it was manufactured. The digital product passport even offers insights into repair and dismantling options, including recycling and correct disposal of the product. The implementation affects all industries and services, with far-reaching effects on almost all corporate business processes.

However, the key to the digital product passport lies in standardized data communication. This enables manufacturers, users and disposal companies to ensure the interoperable exchange of data throughout the entire product life cycle.

Regulations and advantages

The digital product passport is being introduced in various sectors and will be mandatory for batteries from 2027, for example, in the form of the battery passport. It is at the heart of the environmental policy digital agenda of the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV), in close cooperation with the EU Commission. Companies with more than 500 employees are already required to collect most of the information in order to comply with the EU's ESG (Environment, Social, Governance) reporting and the German Supply Chain Act:

- Durability, reusability, retrofittability and reparability of products
- Transparency across the entire life cycle, including the raw materials chain
- Ecological information on greenhouse gas emissions, water consumption and other environmental impacts
- All information relevant to recycling, such as ingredients, potential hazards, instructions for dismantling and correct disposal

As a company, you can also gain further benefits from implementing the digital product passport. It could be expanded with various services and, for example, actively inform about measures that have a positive impact on the service life or service life of a product. In the long term, this product passport can lead to an increase in efficiency in maintenance, service and recycling processes. Processes in the value chain can be planned and controlled much more reliably on the basis of the data.

A practical example: the metal industry

The study "Digital Product Passport: the ticket to achieving a climate neutral and circular European economy?", conducted by the Institute for Sustainability Leadership at the University of Cambridge (CISL) and researchers from the Wuppertal Institute, provides an illustrative example of the use of the product passport:

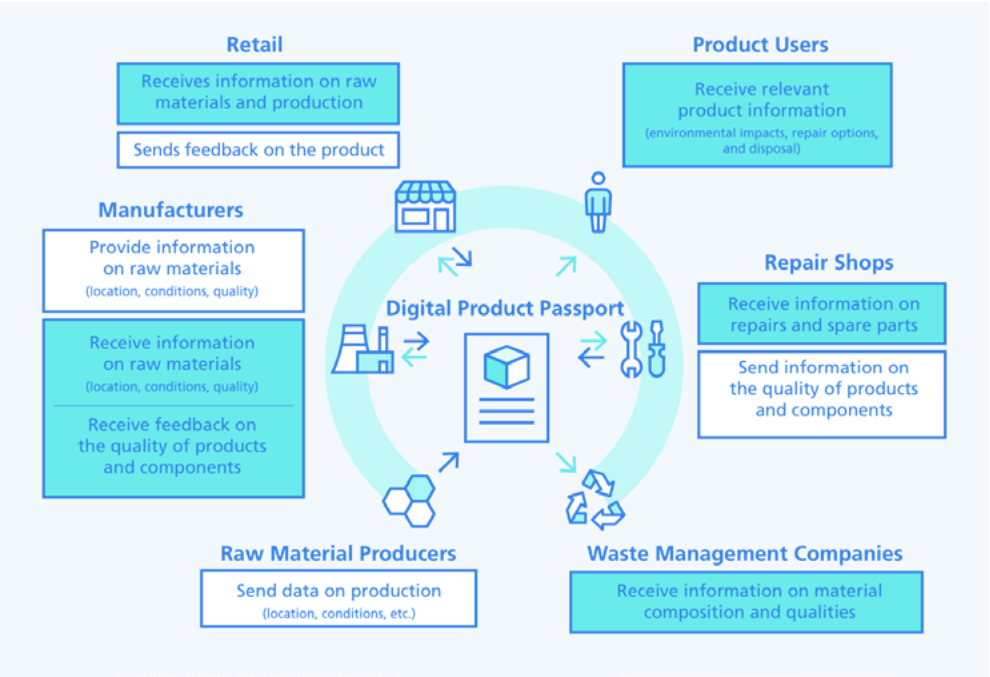
In the metal industry, it is very important to have precise information about the products: Where do they come from, how much energy was used in their production and what emissions are associated with them? Tracking the recycling process is also often a challenge, especially for metals such as aluminum, which have a long lifespan of 35–50 years before they are recycled.

Hydro, a leading aluminum manufacturer, has started a pilot test in collaboration with a customer, a renowned furniture manufacturer. Together they have developed a product passport that contains important information about a bench made from recycled aluminum and wood. This product passport offers consumers the opportunity to gain an insight into the production process and discover the story behind the piece of furniture. This transparency positively influences customers' purchasing decisions, as they can view selected information about the production of the bench and better understand how and where the product and materials were sourced and manufactured.

The technology behind it simply explained

With Eclipse BaSyx, the digital product passport can be implemented for companies in all sectors. Everything is based on this Industry 4.0 tool and the Asset Administration Shell as a sector and industry-wide standard for Digital Twins. This means that a wide range of requirements for the digital product passport can be implemented.

With Eclipse BaSyx, Fraunhofer IESE has created a platform on which standards-compliant communication between machines or goods and software takes place. BaSyx not only provides the IT infrastructure, but also offers additional components that enable rapid implementation of Industry 4.0. This means that different implementation scenarios, such as the digital product passport, can be realized with the same technological basis.



The digital product passport combines the most important elements for promoting the circular economy.

Simply create the battery passport with Digital Twins

From February 2027, the digital battery passport will be mandatory in the EU. It must be provided for all traction batteries, batteries for two-wheeled vehicles and industrial batteries with a capacity of over 2 kWh that are placed on the market here. What purpose does it serve and how can it be easily created? We asked Dr. Thomas Kuhn, Division Manager at Fraunhofer IESE, and Jürgen Hamm, Lead Architect NetApp Twin Solution, about this.

What exactly is a battery passport?

Jürgen Hamm: A battery passport is a standardized digital representation, i.e. a Digital Twin of the physical battery. Ideally, it accompanies the entire life cycle of the battery from design to recycling. As a Digital Twin, it is permanently enriched with current data, for example on the raw materials used, their origin and CO_2 footprint, production, quality data or the entire charging cycle of the battery.

What purpose does it serve?

Thomas Kuhn: The Digital Twin represents the entire life cycle of the battery and is therefore not just limited to production. This improves transparency about the condition of the battery at the end of its use in the vehicle, is the starting point for process improvements to reduce CO2 emissions and facilitates the further use of the battery or the recovery of materials.

How can data be exchanged across company boundaries?

Thomas Kuhn: To achieve this, it is important to define a standard as a uniform technical basis. Plattform Industrie 4.0, as the community of the automation world, the Industrial Digital Twin Association (IDTA) and Fraunhofer IESE, among others, have developed the Asset Administration Shell for Digital Twins. This ensures a standardized interface and thus guarantees that data is machine-readable and can be exchanged across company boundaries.

How can a battery passport be implemented?

Jürgen Hamm: The digital battery passport is an aspect of the Digital Twin of the battery and is technically realized as an Asset Administration Shell Submodel. Fraunhofer IESE, NetApp and Congatec used a demonstrator to show this at the Hannover Messe. It illustrated how the CO_2 footprint of a battery module changes with each production step during battery production.

NetApp provides the necessary intelligent and scalable data management infrastructure to ensure that data is always made available where it is needed and that the number of Digital Twins in an organization can be scaled almost indefinitely. Digital Twins can be created close to the point of origin, can be stored in the local data center or in the cloud.

How can companies easily create digital battery passports?

Thomas Kuhn: Preconfigured solutions for Digital Twins and digital battery passports are provided to make it as easy as possible for companies to get started with digitalization. Fraunhofer IESE, NetApp, Congatec and other partners offer these as software-as-a-service containers as part of the AAS Dataspace for Everybody.

Dr. Thomas Kuhn,
Division Manager
Embedded Systems,
Fraunhofer IESE

Jürgen Hamm,
Lead Architect
NetApp Twin Solution

COMING SOON

BaSyx ROADSHOW

BaSys on site

Industry 4.0 – experience concrete use cases in your area!

Find out more about the use of Eclipse BaSyx middleware in various Industry 4.0 use cases in practice.

Each station will offer you an insight into the potential of middleware. In addition to demonstrations, there will also be interactive workshops and ample opportunity for exchange with users and the Industrie 4.0 experts from Fraunhofer IESE.

From October 2024 to September 2025, the roadshow will stop at the following locations, among others:

- Augsburg
- Berlin
- Hanover
- Kaiserslautern
- Munich
- Saarbrücken
- Scharnhausen (near Stuttgart)
- Ulm
- Weinheim

Further details and dates can be found online!
https://s.fhg.de/basys-roadshow

AAS Dataspace for Everybody – Easy access thanks to preconfigured software containers

New opportunities for production companies with an easy access to data spaces

In a world in which digitalization and data management are becoming increasingly important, industrial data spaces are also coming more and more into focus for manufacturing companies. Cross-company data spaces can decisively help companies to achieve economies of scale, open up new business areas and thus operate more efficiently overall.

However, in order to enable comprehensive networking, the manufacturing processes themselves must already be sufficiently mature. This is precisely where many companies are still reaching their limits. The required software systems are often complex and require specialist knowledge, which in turn makes the digitalization of production very time-consuming and cost-intensive.

The key to digital supply chains

Fraunhofer IESE has taken up this challenge together with NetApp Deutschland GmbH, the Industrial Digital Twin Association (IDTA), Plattform Industrie 4.0, Xitaso GmbH and Congatec GmbH and developed a software-as-a-service solution with the AAS Dataspace for Everybody. This is designed to enable small and medium-sized companies in particular to digitize manufacturing processes, create Digital Twins and integrate them into data rooms. The AAS Dataspace for Everybody offers a platform for the easy sharing of data and preconfigured software solutions based on the open source middleware Eclipse BaSyx. This enables companies to implement Digital Twins along their production lines and thus, for example, calculate their CO_2 footprint, create a batch passport or produce digital product passports. The Digital Twins can then be shared in cross-company data rooms along supply chains – confidently and in compliance with clearly defined specifications. This allows disruptions in the value chain to be identified at an early stage and decisively strengthen the resilience and sustainability of the industry.

Further information:
https://www.iese.fraunhofer.de/en/solution/dataspace.html

Representatives from science and industry came together at the opening of the AAS Dataspace.

AAS Dataspace officially opened

The opening ceremony of the AAS Dataspace for Everybody took place on May 7, 2024. More than 60 representatives from science and industry came together at Fraunhofer IESE in Kaiserslautern to discuss the added value and possible applications of digital data spaces.

Highlights of the opening event included the various applications and usage scenarios of the AAS Dataspace for Everybody. Well-known industrial companies such as SAP, Wittenstein, Thyssenkrupp, Bosch and Mitsubishi were on hand to share their experiences of digital data spaces and Industry 4.0. Research and business partners also gave keynote speeches on the wide range of possible uses.

Comments on the AAS Dataspace for Everybody

Dr. Thomas Kuhn,
Division Manager
Embedded Systems,
Fraunhofer IESE

"The software containers in combination with the embedded middleware Eclipse BaSyx are absolutely unique on the market. With the AAS Dataspace for Everybody, companies of all sizes have the opportunity to integrate data spaces really seamlessly into their production and thus benefit from considerable time and cost savings in digitization."

Bernd Vojanec
Senior Expert
Industrial Digital Twin,
WITTENSTEIN group

"With the AAS Dataspace for Everybody, we at Wittenstein want to publicise the Asset Administration Shells we have already created, network and establish connectivity – from engineering to after sales. We also see great added value in the data that we get back if we also share our product data and models in this Dataspace."

Meik Billmann,
Managing Director
IDTA

"The AAS Dataspace for Everybody is an important milestone for the development of industrial ecosystems based on the Asset Administration Shell. Together with our partners Fraunhofer IESE, NetApp Germany and others, we are proud to provide this opportunity to test business processes along the supply chain in a real industrial ecosystem. Together, we are thus decisively advancing the industrial implementation of interoperable Digital Twins."

Begoña Jara,
Vice President
Area Germany,
NetApp

"The benefits of data do not end at company boundaries. Data must be able to flow easily between suppliers, customers and partners. And data spaces form the basis for this. Anyone interested can already gain important insights and experience today with the AAS Dataspace for Everybody. I am convinced that this will be an important competitive advantage."

SICK AG

What the economy says!

Creation of a harmonized data space for efficient intralogistics

SICK AG is one of the world's leading providers of sensor solutions for automation applications in factories, logistics and processes. As a technology and market leader, SICK uses sensor intelligence and application solutions to create the basis for the safe and efficient control of processes, for the protection of people from accidents and for the prevention of environmental damage.

The company manages its intralogistics using an event-based dynamic scheduling system with the aim of increasing efficiency and flexibility. To achieve this goal, asset interfaces must be harmonized and data silos broken down to create an integrated and harmonized data space.

SICK quickly recognized the advantages of implementing Asset Administration Shells (AAS) with Eclipse BaSyx for this purpose. In close collaboration with Fraunhofer IESE, SICK defined its own submodel templates and used the Eclipse BaSyx Java SDK to implement an AAS generator tailored to SICK's needs. By using various BaSyx components and functions, SICK was able to set up the administration shell for productive use within a few days.

"By using Eclipse BaSyx, we were able to put the Asset Administration Shell into productive use within just a few days."

SICK AG

As a result of the project, SICK now has an AAS-based logistics scheduling system that breaks down data silos and creates harmonized interfaces for assets. This has not only enabled the company to achieve its goals, but also to benefit from other features of the AAS ecosystem, such as the AAS GUI and easy integration with other AAS-based solutions. The implemented system is now used in a number of factories and enables further use cases such as asset and factory monitoring

BaSyx creates the interface for assets and factories

Digital Twins in practice

How Digital Twins are transforming the automotive industry

Interview with Dr. Pablo Oliveira Antonino, Department Head Virtual Engineering at Fraunhofer IESE

The two IESE technologies, Eclipse BaSyx and FERAL, complement each other in the creation and application of Digital Twins: BaSyx provides a standardized description of physical objects that can be used for simulations with FERAL. Both solutions illustrate Fraunhofer IESE's expertise in the field of Digital Twins. In this interview, Dr. Pablo Oliveira Antonino explains the special features of FERAL and the benefits that customers gain from using the simulation framework.

What makes FERAL special?

FERAL is a versatile toolbox designed to create highly complex Digital Twins for a wide range of components, particularly within the automotive sector-covering both on-road and off-road applications. It supports the modeling of embedded electronics, ECUs, and in-vehicle communication systems like CAN, CAN XL, Lean, and FlexRay. Beyond Digital Twin creation, FERAL enables comprehensive simulation capabilities, allowing users to explore "what-if" scenarios. This helps predict the impact of various decisions and verify whether the system behaves as expected, ensuring informed decision-making and enhanced system reliability.

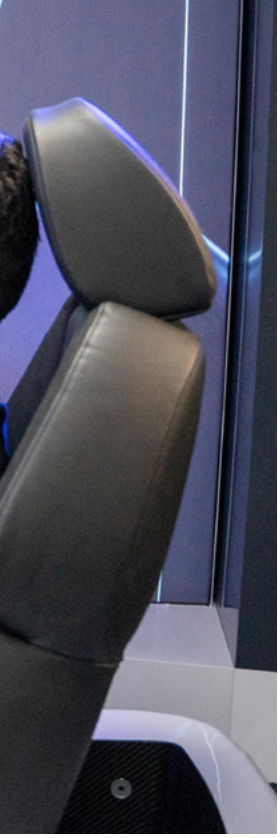
Can you give us an example of what can be simulated with FERAL?

Recently, we completed a project examining the impact of security vulnerabilities on vehicle safety. With modern vehicles connected to the internet, the risk of a hacker accessing a car's systems raises serious concerns. Imagine driving on the highway at 200 km/h when an attack suddenly compromises control systems, preventing you from stopping the vehicle – an extremely dangerous scenario. Using FERAL, we create Digital Twins of critical vehicle components, enabling us to test potential attack scenarios in a virtual environment to enhance vehicle safety.

Just last week, a company manager highlighted the value of FERAL, saying, "You've already saved us thousands of physical tests. FERAL not only brings thousands of scenarios into the virtual world with Digital Twins but also simulates and analyzes their potential outcomes for us." This capability underscores FERAL's role in advancing secure and resilient automotive systems.

What unique advantages does FERAL offer over other solutions?

The key lies in its customizability and vendor independence. Unlike commercial providers, we're not tied to specific tools or brands, which allows us a unique advantage: we can integrate solutions from various vendors. For instance, through a strategic partnership with the U.S. company ANSYS and its European partner CADFEM, we've developed a demonstrator that combines CARLA for 3D modeling, Matlab/Simulink for functional modeling, and several other technologies. Ultimately, FERAL enables high-precision simulations of various vehicle controllers and communication systems by integrating features from multiple tools, each precisely suited to the specific goals of each analysis.



"Ultimately, FERAL enables high-precision simulations of various vehicle controllers and communication systems by integrating features from multiple tools, each precisely suited to the specific goals of each analysis."

Dr. Pablo Oliveira Antonino
Department Head Virtual Engineering

Equally important, as scientists, we incorporate the latest research advancements into FERAL. This keeps our software adaptable to the evolving needs of our industrial clients and enables us to deliver precise, cutting-edge analyses that directly address today's complex challenges, like integrating such complex analysis into CI/CD pipelines.

What collaboration options are available for companies?

Here's how the process typically works: A customer approaches us with a specific requirement, such as assessing the impact of security on vehicle safety. We then tailor FERAL internally to meet these requirements, creating Digital Twin models and identifying the key elements to analyze. Following this, we deliver a comprehensive diagnosis and strategic recommendations to the customer. In this approach, the customer receives the final results but does not directly access FERAL.

Alternatively, customers can choose to use FERAL within their own infrastructure. Through a license model, FERAL becomes available for internal use, with the added benefit of development support included as part of the license.

We're also introducing a new option: "Digital Twin or Simulation as a Service." In this model, FERAL remains fully integrated into our IESE infrastructure, providing customers with remote access to FERAL without the need for installation within their own systems. This solution offers an efficient and convenient way for companies to leverage FERAL's capabilities.

In which companies is FERAL used?

FERAL is used, for example, in our long-standing collaboration with Robert Bosch. Since 2016, we have assisted Bosch in developing Digital Twins and simulating vehicle communication systems, including those for autonomous driving functions. Bosch integrated the FERAL Virtual Bus into their SiL Framework, which significantly improved their network verification process. This integration not only streamlined the simulation of network scenarios but also accelerated their time to market.

PODCAST TIP

Digital Twins – utilizing potential

Find out more about how the FERAL solution is used. (German version)

Testing driver assistance systems in virtual worlds with FERAL

Testing driving functions typically requires thousands of kilometers of test drives after every software update. The later errors are identified in the software development process, the more significant the delays and costs associated with corrections become. To address this challenge, Fraunhofer IESE offers an efficient solution for developing programs for modern advanced driver assistance systems (ADAS).

With FERAL from Fraunhofer IESE serving as a tool for virtual test benches, companies can conduct virtual test drives at a scale that would be impractical for real-world testing. Utilizing virtual test benches accelerates development processes, making expensive and limited hardware-in-the-loop (HiL) test benches obsolete. This approach allows for continuous, faster, and more accurate detection of design and software errors.

A notable advantage of FERAL is that the simulation framework supports remote work, enabling the test team to easily validate driving functions from home.

How does FERAL work as a toolbox for virtual test benches?

FERAL enables the seamless integration of various simulators and executable software components across different abstraction levels, facilitating the creation of executable virtual test scenarios tailored for CI/CD pipelines (continuous integration and delivery). The toolbox incorporates a diverse array of components, including E/E platforms, network simulations, driving functions, and models for drivers, cameras, and environmental conditions. This comprehensive integration guarantees that FERAL offers a robust and flexible environment for virtual testing.

The advantages of FERAL at a glance

1. Testing ADAS functions through millions of virtual kilometers
2. CI/CD for the development of vehicle functions
3. Evaluation of system stability by injecting errors
4. Implementation of test scenarios on realistic virtual platforms
5. Can also be used for mobile working models

Further information:
https://www.iese.fraunhofer.de/en/services/digital-twin/feral.html

embedded world 2024

Fraunhofer IESE presented its latest developments in the validation of driving functions in virtual worlds at the embedded world Exhibition & Conference 2024 in Nuremberg from April 9 to 11, 2024.

A special highlight of Fraunhofer IESE's presence at the joint booth of the Fraunhofer-Gesellschaft was the driving simulator, which uses FERAL to validate new driving functions efficiently and at an early stage. The IESE experts demonstrated on site how companies can use FERAL to detect errors early on in the development process of their advanced driver assistance systems.

FILM TIP

Vehicle innovation through simulation

Find out more about how the FERAL solution is used.

Robert Bosch GmbH

What the economy says!

Bosch analyzes electronic control units with FERAL

Fraunhofer IESE and Robert Bosch GmbH have been working together since 2016 to virtually integrate and validate ECUs in SiL (Software in the Loop) frameworks. The IESE technology FERAL is used for this purpose.

Bosch commissioned Fraunhofer IESE to customize FERAL for various analyses during ECU development. One of the key applications involved integrating multiple system components into a unified simulation model to deliver crucial quality metrics, such as vehicle bus utilization and response times. Bosch equipped the virtual ECUs with interfaces, integrated simulators for vehicle dynamics, and utilized FERAL for simulating vehicle buses (CAN and FlexRay). This simulation system allows for detailed observation of system behavior and the analysis of critical states. Additionally, Bosch has licensed FERAL to support further tasks in virtual engineering.

"We have successfully integrated the FERAL Virtual Bus into our SiL framework, which has significantly improved our network verification process. This not only allowed us to easily simulate network scenarios, but also shortened our time to market."

Shenoy Ganesh
Tech Expert,
Bosch Global
Software Technologies

VALU3S project – efficient validation of automated systems

In the VALU3S project, Fraunhofer IESE collaborated with approximately 40 partners from academia and industry to test and validate the safety of automated systems, with support from the European Union (ECSEL Joint Undertaking).

VALU3S stands for "Verification and Validation (V&V) of Automated Systems' Safety and Security." The project's objective was to develop advanced V&V methods and tools to streamline the testing of security, cybersecurity, and data protection for automated systems.

To ensure the safety and reliability of automated systems for market launch, they must meet stringent safety standards. However, the complexity of these systems often makes the V&V process time-consuming and costly. As part of VALU3S, a comprehensive framework was developed to centralize all relevant information about the V&V process, thereby simplifying it and reducing both costs and time. This framework also aids in identifying vulnerabilities and developing effective V&V concepts.

Within the project, Fraunhofer IESE focused on solutions for the early virtual validation of product properties. The institute enhanced its own simulation and validation tool, FERAL, which was utilized and validated in an industrial case study in the field of automation technology.

Virtual validation replaces time-consuming field tests in agriculture

Complex field tests will soon be a thing of the past

In collaboration with Balanced Engineering LLC, Fraunhofer IESE developed a concept to improve and advance the testing and development of autonomous agricultural vehicles.

Together with Balanced Engineering, a consulting company for agricultural machinery manufacturers, the Fraunhofer IESE team implemented the project "Virtual Validation and Development for Autonomous Agricultural Vehicles" in order to optimize the development and testing of autonomous agricultural vehicles. The project included the creation of a virtual simulation environment with the "Car Learning to Act" simulator (CARLA), which simulates realistic agricultural scenarios.

Increasing the efficiency of agricultural vehicles with the help of FERAL

By integrating different sensors, ECU and actuator models, autonomous tractors could be tested under different weather conditions and in different obstacle situations. The simulation framework FERAL, developed by the experts at Fraunhofer IESE, enables the connection of multiple simulators and models to validate the decision-making and performance of the vehicles. Different scenarios – from optimal visibility conditions to extreme weather conditions – were simulated in the project with Balanced Engineering to evaluate and improve the robustness and efficiency of the autonomous systems.

Replacing expensive field tests for autonomous agricultural machinery with simulations

Balanced Engineering approached Fraunhofer IESE with the challenge of creating an efficient and realistic test environment for autonomous agricultural vehicles. The goal was to validate and optimize the performance and safety of these vehicles under different conditions – without having to rely on costly and time-consuming field tests.

Virtual validation with FERAL increases the performance of tractors

Fraunhofer IESE supported Balanced Engineering by developing a comprehensive virtual simulation environment based on the CARLA simulator. This environment made it possible to simulate realistic agricultural scenarios and integrate various sensor, ECU, and actuator models. The FERAL tool played a crucial role in this by connecting different simulators and models and allowing flexible, event- and time-controlled simulation.

This enabled the project team to implement automated test pipelines and ensure the continuous integration and validation of the autonomous systems. By simulating different scenarios – from ideal conditions to extreme weather conditions – the performance of the tractors in terms of object recognition, decision-making, and safety mechanisms could be comprehensively tested and improved.

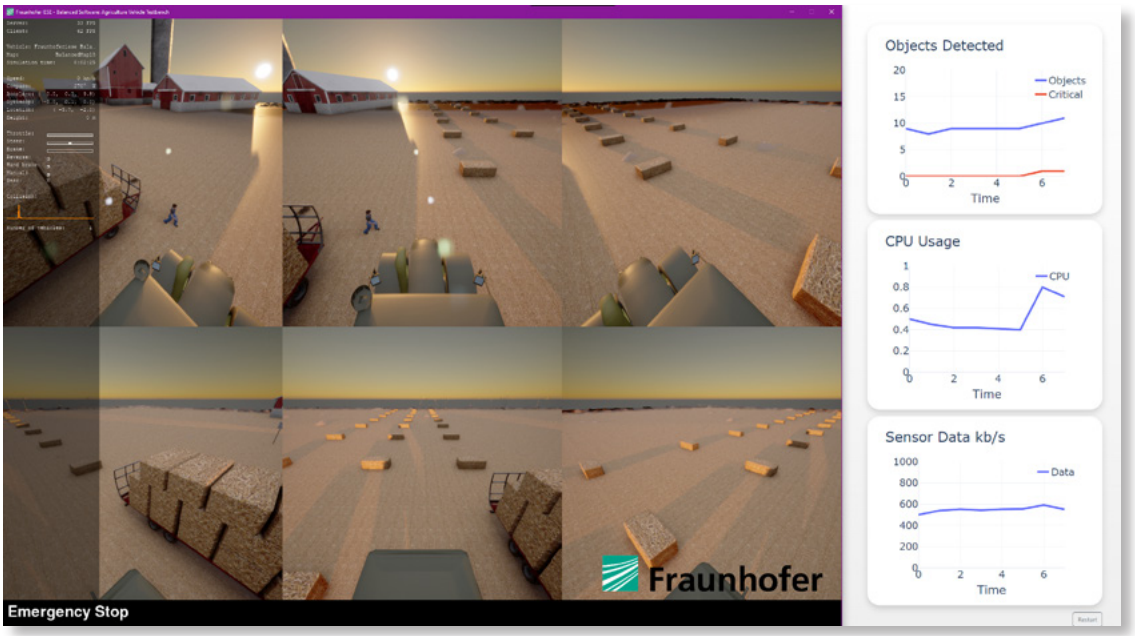
The detailed evaluation of the simulation results, including analysis of processor load and sensor performance, helped to optimize the vehicle architecture and ensure efficient data processing and transmission.

New test environment drives efficiency and sustainability in agriculture

The project resulted in a robust virtual test environment that enables autonomous agricultural vehicles to be efficiently tested and optimized under a variety of conditions. The methods and tools developed made a significant contribution to improving the safety and performance of autonomous tractors. In the future, Balanced Engineering plans to further utilize the knowledge and technologies gained to advance the development of autonomous agricultural systems – and thereby increase efficiency and sustainability in agriculture. The collaboration with Fraunhofer IESE laid the foundation for further innovative projects in the field of autonomous vehicle technology.

"In our recent projects with one of the world's leading manufacturers of agricultural machinery, the contribution of Fraunhofer IESE as subcontractor was an essential support for the high customer satisfaction that we achieved."

Rick Weires
Partner at Balanced Engineering LLC



Monitoring of simulations with FERAL and CARLA for the validation of autonomous agricultural vehicles.

Dependability of systems

Fraunhofer IESE utilizes Digital Twin technology to ensure the dependability of systems

Interview with Dr. Daniel Schneider, Division Manager Dependable Systems at Fraunhofer IESE

An important research area at Fraunhofer IESE deals with the dependability of systems. Particular focus is on safety and security with two dedicated departments. When ensuring safety and security in next generation system of systems, digital twins can be of great use. In this interview, Dr. Daniel Schneider explains how the Digital Twin is used and what role it plays in making systems more dependable.

Dr. Daniel Schneider
Division Manager
Dependable Systems

How can Digital Twins help to ensure dependability of systems?

In general, Digital Twins are digital representations of systems that describe certain aspects of the systems – but which can be updated dynamically and continuously. Current data from a running process, the system, and the environment are always incorporated, creating an accurate representation for a specific aspect of the system in the Digital Twin. To a certain extent, we have been working on this topic for over 15 years – longer than the term Digital Twins has actually existed. We used to call it Models@Runtime. This means creating models of systems and utilize them at runtime in order to support aspects such as dynamic adaptation or the guarantee of safety and security. In terms of guaranteeing safety and security, the aim is often to monitor and evaluate dynamic changes in the system or context in order to be able to react appropriately at runtime.

In recent years, we have increasingly been looking at the dependability of systems with Artificial Intelligence and, in particular, with neural networks. One specific approach is our Uncertainty Wrapper, which is a kind of Digital Twin that continuously makes statements about the uncertainty of the AI output at runtime.

What are the advantages of Digital Twins for dependability?

This depends heavily on the application. Ideally, runtime models enable that the performance of a system can be significantly improved. Instead of acting on the basis of worst-case estimates, systems can now monitor and evaluate the actual situation and then only do what is really necessary to ensure dependability.

Another positive example comes from pharmaceutical production. As part of the RNAuto flagship project, we are using the Digital Twin for quality assurance of pharmaceuticals. Each device in the production process was equipped with a modular Digital Twin in order to comprehensively monitor the production process and dynamically incorporate all relevant parameters. If the quality deviates, it is possible to intervene to minimise this. Automatic quality documentation can also be created, as all relevant data is already stored in the Digital Twins.

What other use cases are there?

We are currently increasingly dealing with dynamic systems that integrate at runtime. If this is the case, the systems often come from different manufacturers and are supposed to come together and work together ad hoc. According to our approach, each of these individual systems has its own Digital Twin that describes all the key characteristics of dependability. This allows automated analyses of dependability properties of the integrated overall system, which can then be continuously monitored and controlled.

Apart from that, we deal with systems at development time and their supply chains. It is often the case that various suppliers deliver components to an OEM, the original equipment manufacturer, and the OEM has the task of integration. Here we have the challenge of correctly integrating the models and work products for the dependability properties, which are often quite extensive and complicated. On the basis of our Digital Twins for dependability – so-called digital dependability identities – such integration scenarios can be partially automated supported by dedicated modeling tools such as our own modeling tool – safeTbox.

Is the Digital Twin becoming increasingly important for dependability – even in industry?

The term "Digital Twin" has clearly experienced a hype, especially in the area of production. But there are indeed promising ideas with plenty of potential here. The term is also increasingly being used in other domains. For example, we are currently researching various applications of Digital Twins in the healthcare sector, such as Digital Patient Twins to improve preventive care.

What the economy says!

Robert Bosch GmbH

Bosch accelerates software development cycles through systematic change impact analyses

In certain industries, such as the automotive industry, system security is of the utmost importance, but is also associated with high costs. Particularly in systems that are affected by frequent changes, such as autonomous vehicles, inefficient change management leads to a waste of development resources and long update cycles for functions.

In the project with Robert Bosch GmbH, Fraunhofer IESE addressed the question of how safety engineers can receive better support in determining the effects of changes to new or updated driving functions, critical faults, or new findings about hazards. The IESE experts developed a web-based tool for interactive change impact analyses, i.e. for analyzing the effects of changes. The new tool enables Bosch to efficiently and contextually analyze which elements of the safety case are affected by a proposed change.

New IESE tool improves security at Bosch with Digital Twins

The Fraunhofer IESE team reviewed and evaluated the approach used by Bosch's safety engineers and identified numerous scenarios where a change-impact analysis would be beneficial for development processes according to the ISO 26262 standard. As a result, the example scenario provided by Bosch was converted into a Digital Dependability Identity (DDI). This means that Digital Twins of the relevant system aspects and the associated security analysis artefacts were created.

However, the most important advantage of switching to a DDI was that the IESE engineering team was able to extend the model's the representation of the model with a (meta) model for tracing the effects of changes. In this way, the Digital Twin now 'knew' how changes to certain parts of the model would affect other parts of the model.

The new tool is designed for collaborative work, allowing colleagues in safety teams to repeat analyses and integrate their results clearly within the model. This approach prevents both confusion and loss of information.

To make the visualisation of change-impact analyses more user-friendly, additional interactive features were implemented, such as hiding sub-trees and recursively labeling affected nodes. Ultimately, IESE created a comprehensive documentation covering the use of the tool, the methodology, the background research, and the evaluation of the tool using a sample system.

"In close collaboration, Fraunhofer IESE developed a proof-of-concept tool that already supports basic change scenarios."

Markus Schweizer
Project Manager Central Research,
Robert Bosch GmbH

Further information:
www.iese.fraunhofer.de/en/reference/bosch-software-development-cycles.html

Hitachi, Ltd.

Hitachi realizes the next generation of urban mobility

In Hitachi City, Japan, autonomous shuttles are set to improve the bus rapid transit (BRT) system. Hitachi-City wants to increase the efficiency and dependability of public transportation and at the same time counteract the future shortage of qualified drivers. These autonomous shuttles operate on special BRT roads, which ensure a smooth and uninterrupted journey away from regular traffic. However, the BRT roads cross regular lanes and crosswalks, which increases the potential risk of collisions and therefore harm to both other road users and bus passengers.

Hitachi, Ltd. has recognized these challenges and developed a dynamic safety engineering process in collaboration with Fraunhofer IESE. This innovative solution increases the safety of autonomous shuttles, especially in interactions with pedestrians and other road users.

Traditional approaches versus new security models

In conventional approaches, worst-case assumptions are often made when operating the autonomous vehicle, particularly with regard to the behavior of pedestrians. This method leads to overly conservative reactions at crosswalks and thus to a performance that lags behind that of human drivers. Such cautious behavior can be detrimental to the effectiveness, utility and acceptance of autonomous shuttles by both operators and passengers. To address this issue, new solutions are needed that balance functional safety and operational efficiency in highly dynamic urban environments.

In a joint project with Hitachi, the experts at Fraunhofer IESE have developed various models for dynamic safety using the "Digital Dependability Identities" technology into executable software and integrated into the real target system architecture of the autonomous shuttle bus or BRT system.

The overall system, including the various technologies, was successfully tested for crosswalks both in simulations in Digital Twins and on a real system at a closed test site on the Hitachi campus in Japan. The autonomous bus was not overly cautious and its performance was comparable to that of a human driver. With the expertise gained, Hitachi, Ltd. is now well positioned to apply the dynamic safety engineering process in other use cases and future development projects in various fields.

"The security technology developed was demonstrated in a real environment in collaboration with Fraunhofer IESE, which has extensive knowledge of industrial applications."

Dr. Masaya Itoh
Senior Manager,
Research department for autonomous control,
Hitachi, Ltd.

Further information:
www.iese.fraunhofer.de/en/reference/hitachi-ltd-next-gen-urban-mobility.html

Revolution in the healthcare sector?

Digital Patient Twins improve diagnosis and therapy

Creating a Digital Twin of a static machine is certainly already demanding But how much more complex must it be to digitally recreate dynamic organisms like humans? Fraunhofer IESE is addressing the associated challenges and potential of Digital Patient Twins in the digital health domain. The institute's researchers are contributing their extensive expertise so that the efficacy of medications could be tested on the digital twin- even before a real person swallows the first pill.

What is a Digital Patient Twin?

Basically, the Digital Twin of patients is defined as a virtually precise, dynamic simulation of biological entities. Such a highly developed model can, for example, replicate cell structures, tissue, organs or entire patients and ideally contains all the information of the real counterpart. Digital Patient Twins are dynamic, i.e. they take into account changes over time and can simulate basic physiological processes, making it possible to make predictions about physiological functions, for example when taking certain medications.

The path to predictive health monitoring

Digital Patient Twins have enormous potential for a wide range of applications. For example, the models could help to visualise metabolic processes in the body. A great opportunity in medicine is that the digital twin can be used to clarify the effect, interaction or side effect of a medication – before a person takes the drug for the first time. This is similar to a Digital Twin in production, where machines can be maintained with foresight: The way is therefore paved for predictive health monitoring. And new doors are also opening up in terms of prevention, as the virtual image can indicate the onset of a disease at an early stage or reveal an increased, specific risk of illness. This means that patients can be protected from long-term consequences by taking timely countermeasures.

Digital Patient Twinning could also have a favourable effect on the topic of 'clinical studies': it should be hopefully become possible to simplify such studies on real people and shorten their duration by simulating the efficacy or dosage by Digital Patient Twins in advance. There are a few examples of clinical studies worldwide with Digital Patient Twins, with diabetes as a leading disease in several cases.

The challenge of the human organism

In principle, we have extensive knowledge about the molecular mechanisms – in other words, how cells work and interact with each other. However, humans are not machines that can be precisely replicated and predicted. Therefore, Digital Patient Twins will always face the challenge that this molecular complexity cannot be directly replicated, at least with todays technologies.

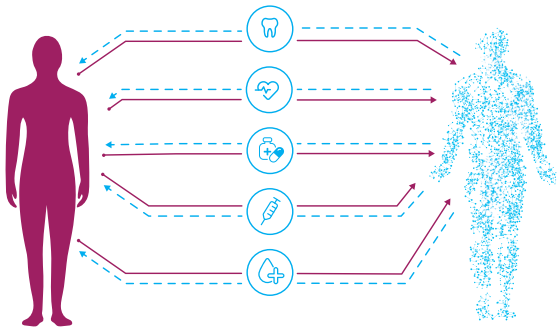
Despite the necessary abstraction and limitations, digital twins like the replication of individual organs, can still support medical advances A good example of this is the successful use of a Digital Twin Heart in cardiology. Ano-her example is the digital lung twin, which is individualised for patients. In future, this twin model will enable doctors to use computers to test various treatment and ventilation methods in advance – with the aim to ventilating each patient as gently as possible.

Enormous amounts of data are the basis

In order to create Digital Patient Twins, huge amounts of high-quality (medical) data is needed– in other words, long-term data covering a person's entire life. Assuming that all the data were available, it would still be a technical challenge to integrate the information from different data sources into a shared database. And data protection is of course also a sensitive and crucial aspect in this context. Who is authorised to access this data and from where? Who authorises access? The dependability and trusworthiness of the algorithms on which these analyses are based is also a decisive and not uncritical factor as medical decision would be based on the mathematical outputs.

Digital Patient Twins promise enormous potential for medicine, as they will hopefully soon be possible to detect diseases at an early stage – ideally before symptom onset. Fewer diseases through more prevention and a treatment reduction could be the future. Fraunhofer IESE is working on this with its extensive expertise in Digital Twins, Data Science and Data Protection.

Further information on digitalization in the healthcare sector:
www.iese.fraunhofer.de/en/trend/digital-health.html



The Digital Patient Twin can map physiological processes in the human body.

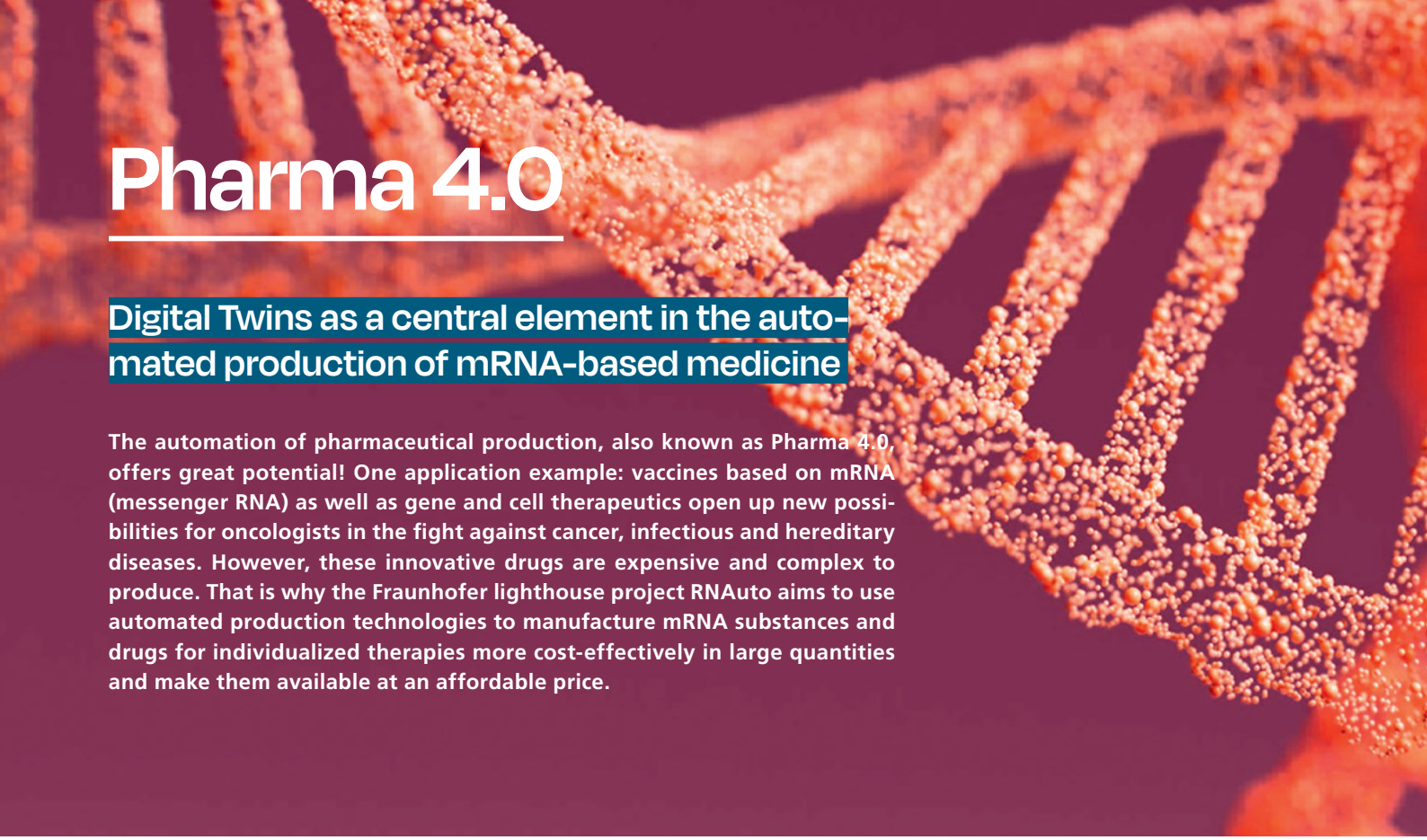
Digital Twin Hackathon

The Digital Twin Hackathon took place at Fraunhofer IESE in October 2023. Creativity was in the air and keyboards clicked to the rhythm of innovation – all in a race against time. Within 24 hours, 13 teams took up the challenge of using the Industry 4.0 middleware Eclipse BaSyx to bridge the gap between cutting-edge medical therapies and their manual production.

The winning team of the hackathon presented an approach in which Digital Twins are used to improve laboratory facilities in order to facilitate equipment management. The second-placed team used AR glasses, Digital Twins and AI models to optimise laboratory operations and increase the efficiency of experiments. The team that came third focused on creating a Digital Twin for laboratories to optimise workflows and improve data transfer. All of these innovative solutions illustrate the potential of digitalisation in the healthcare sector.

Many creative minds coded at the Digital Twin Hackathon at Fraunhofer IESE.

Here are some impressions of the Digital Twin Hackathon and further information:
https://basyxhack.iese.de/



Pharma 4.0

Digital Twins as a central element in the automated production of mRNA-based medicine

The automation of pharmaceutical production, also known as Pharma 4.0, offers great potential! One application example: vaccines based on mRNA (messenger RNA) as well as gene and cell therapeutics open up new possibilities for oncologists in the fight against cancer, infectious and hereditary diseases. However, these innovative drugs are expensive and complex to produce. That is why the Fraunhofer lighthouse project RNAuto aims to use automated production technologies to manufacture mRNA substances and drugs for individualized therapies more cost-effectively in large quantities and make them available at an affordable price.

In order to offer tailored, personalized therapies to as many patients as possible, fully digitalized, automated production processes are required. In the lead project RNAuto, seven Fraunhofer Institutes have been pooling their expertise in the fields of medicine, biology and engineering since the beginning of 2022 in order to produce mRNA vaccines and gene and cell therapeutics that use mRNA as a starting material automatically, quickly and cost-effectively in large quantities.

Modular screening system for the production of mRNA substances

One focus of the research work is the development of a screening platform that is scalable up to industrial scale with digital process control and data-driven online quality control, with which mRNA can be encapsulated in lipid nanotransporters. The project team is initially aiming for mRNA drug production on a laboratory scale of up to 20 ml. In cooperation with the Fraunhofer Institutes for Microsystems and Microtechnology IMM, for Production Technology IPT and for Cell Therapy and Immunology IZI, the Fraunhofer Institute for Experimental Software Engineering IESE is coordinating the design and construction of the automated, component-based screening system. The system, measuring 1.4 m x 0.8 m x 1.6 m, consists of scalable, flexible and manufacturer-independent production modules that can be easily replaced in the event of a defect.

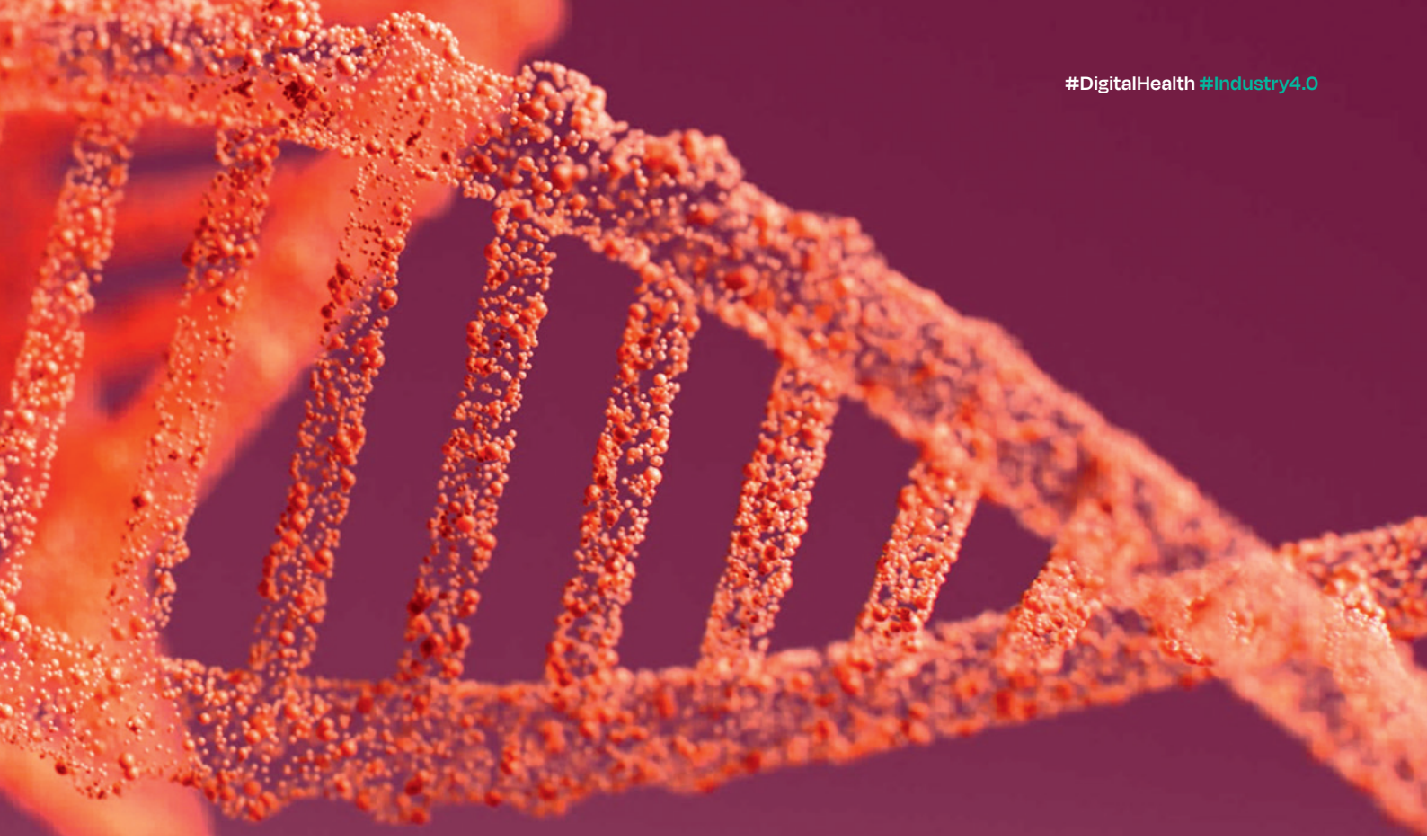
Use of Digital Twins in quality control and process control

In order to produce a dependable mRNA drug, consistent product quality must be guaranteed, including, for example, quantification of the amount of encapsulated mRNA in the nanotransporters. The uneven ratio of encapsulated mRNA at the start of the mixing process and high flow rates in the production process pose challenges for continuous quality control. Due to the resulting fluctuations in the viscosities of the mixture, refractive indices, conductivities, temperatures and pH values and the corresponding influence on product quality, not only process optimisation but also comprehensive quality control and documentation of the fractions is crucial.

Quality assurance and process control, i.e. the control of pumps, mixers and further devices, are fully digitally mapped – via Digital Twins and AI-supported software tools – a novelty in the production of mRNA active ingredients. To this end, the researchers are using their experience from Industry 4.0 and are utilizing software such as the Industry 4.0 middleware Eclipse BaSyx from Fraunhofer IESE and the process control software COPE from Fraunhofer IPT. Digital information for process monitoring and quality assurance is recorded via the Digital Twins of the individual components. One example is the DLS (Dynamic Light Scattering) detector, a messurement technique for characterizing particle sizes in emulsions. Further data is recorded via temperature and pressure sensors, flow sensors, viscosity sensors and pH sensors. Each component is represented by its own Digital Twin.

Digital Twin enables online analytics and digital documentation

With the screening system, the project partners can determine the optimal combination of mRNA and lipids and the best degree of packaging. Each individual test with changed parameters can be recorded digitally using the Digital Twin of product quality. Any errors, such as temperatures that are too low, are documented

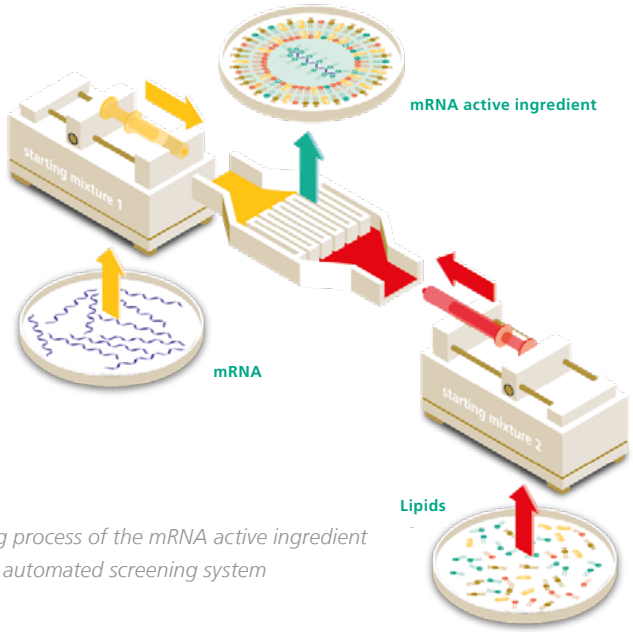


#DigitalHealth #Industry4.0

in this way and the associated information is made available digitally.

In the final expansion stage, the Digital Twin will be able to initiate appropriate corrective measures in such a situation. With the integrated online analytics, the quality can be automatically measured during the manufacturing process and the optimum active ingredient composition and production parameters can be determined. The system will enable automated, component-based, flexible and validatable production, bringing the vision of Pharma 4.0 production closer step by step. Upon completion, the team of researchers will be able to produce 20 ml of mRNA active ingredient in a quality-assured manner within a few seconds.

Once the screening platform has been completed, a mRNA vaccine against West Nile fever will be produced as part of the research project. The vaccine will be tested for its effectiveness at the Fraunhofer IZI in Leipzig. By the end of 2025, it should be fully developed at the Fraunhofer IMM in Mainz and also made available to industrial partners.



Mixing process of the mRNA active ingredient in the automated screening system

Further information:
https://www.iese.fraunhofer.de/de/referenz/rnauto.html

The future of cities

How Digital Twins are transforming Smart Cities

Cities are the beating heart of society. Over the years, they have developed into complex systems, which is why improving their sustainability is a challenging task. The use of Digital Twins can help and promote quality of life and sustainability in urban areas. Fraunhofer IESE has the necessary expertise to support cities on their way to becoming Smart Cities.

The concept of the Smart City

Cities should not just be seen as a collection of physical units. Rather, they are a system of interlocking building blocks that can respond to the needs of their inhabitants and the dynamics of their environment and communicate with each other. With advances in information technology and digitalization, the concept of the Smart City has been introduced to cleverly connect these units and create added value. Smart Cities use digital technologies, communication technologies and data analytics to build and expand an efficient and effective service environment that improves urban quality of life and promotes sustainability. These technologies can be used in various areas such as healthcare, mobility, education and administration.

The heart of the Smart City

An urban Digital Twin is a digital model of a planned or actual physical product, system or process. This model uses live data from sensors distributed throughout the city to visualize and simulate the behavior of various components of the city. For example, data on the traffic volume or the parking situation at certain times of the day. Urban Digital Twins have a remarkable impact on improving the sustainability of cities. With the help of the data they collect and the analyses they perform, it is possible to gain a deep understanding of the conditions on the ground and recognize how the various entities interact with each other and with the environment currently and in different scenarios. All of this helps to maintain the three pillars of sustainability – social, environmental and economic sustainability – and promote lasting urban development.

The three pillars of sustainability

1. Social sustainability

Social sustainability revolves around the preservation and development of social capital. The use of Digital Twins in digital city administration applications can facilitate citizen participation and support a collaborative decision-making process. A good example of this is a Digital Twin for urban planning, which is used to plan facilities such as clinics, markets and cafés. If the city planner can merge the requests and wishes of citizens directly with the knowledge of the condition and requirements of local facilities through the Digital Twin, they can find the best location that meets the needs of the population.

2. Environmental sustainability

Protecting the environment and preserving the ecosystem are the main objectives of environmental sustainability. Digital Twins can help mitigate the effects of some climate change-related disasters, such as floods or heat waves, and protect the environment. For example, by placing sensors in the soil of green spaces, it is possible to continuously measure vital indicators such as soil moisture, air quality and temperature. These indicators play an important role in the preservation of the vegetation ecosystem, in which planning for the future is based on the measurement data collected and the scenarios developed from it.

3. Economic sustainability

Continuous monitoring of energy consumption data and information on people's needs and the state of the environment lead to more efficient use of resources. As a result, energy consumption can be minimized and economic and cost-effective units can be created in the city. This also has an impact on the attractiveness of the city as a place to live and do business.

A good example of how a city can significantly reduce energy consumption is the control of street lighting – depending on sunlight, time of day and traffic. The street lighting is dimmed on sunny days or even at night when the streets are empty and there is no traffic. This is done by installing optical sensors that calculate the desired lighting level via a central management system and then control the street lighting accordingly. In the village of Urdorf in Switzerland, for example, energy consumption has been reduced by 70 %.

Turning sustainable cities into reality

The transformation to Smart Cities through the use of urban Digital Twins promises a lasting and livable future for urban areas: By taking social, ecological, and economic aspects into account, cities can be designed more efficiently and in a way that preserves resources. The Smart City experts at Fraunhofer IESE provide support in this regard by opening up a seamless transition between the analog and digital world and turning sustainable urban development into reality.

Reading tip

Study: Digital Twins – potential in urban development

An urban Digital Twin is a digital model of a city or district. For example, municipalities can use it to simulate traffic or the consequences of heavy rainfall and create other scenarios for urban development. A publication issued by the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR) entitled "Digital Twins – Potentials in urban development" shows how Digital Twins can be set up successfully.

The publication is the result of the accompanying research of the Coordination and Transfer Office Smart Cities (KTS). The Fraunhofer Institute for Experimental Software Engineering IESE and the Fraunhofer Institute for Industrial Engineering IAO jointly developed the study.

Note: Interested parties can access the German publication online or order a printed copy free of charge by email at: publikationen.bbsr@bbr.bund.de

Imagining the city of tomorrow

Fraunhofer IESE accompanies the city of Braunschweig toward a Digital Ecosystem

The goal and vision for the use of urban data platforms (UDP) and urban data twins (UDT) is identical for most of these implementation projects: new, unused data sources in a municipality are to be digitally recorded and existing data silos in administration and business are to be broken up and their data merged into a common platform. This should allow intelligent control of municipal infrastructure, processes and goods in order to enable more efficient, improved or completely new services for public, private and commercial purposes. But how are such systems established in a city? There is no one-size-fits-all recipe for a municipality to enter the world of UDP and UDT, as all localities are unique. This is also shown by the city of Braunschweig's project to plan its digital municipal future.

A concept as individual as the city itself

Every city faces its own geographical, economic, social – and increasingly also climatic – challenges. It is uniquely organized and has an individual, historically evolved digital infrastructure. However, this existing infrastructure can only be integrated and expanded step by step. To this end, the focal points and specific use cases for the first steps toward a data platform and Digital Twin must be individually designed and planned. The development of such a Digital Ecosystem is never complete: as long as the city changes, the ecosystem must change with it.

The city of Braunschweig has secured powerful planning support for its journey toward a digital municipal future: Initiated by the Geoinformation Department of the City of Braunschweig, Fraunhofer IESE is working on a subcontract from the "PD – Berater der öffentlichen Hand GmbH". PD works exclusively for public clients in matters of strategic administrative modernization as well as in the areas of construction, infrastructure and municipal consulting.

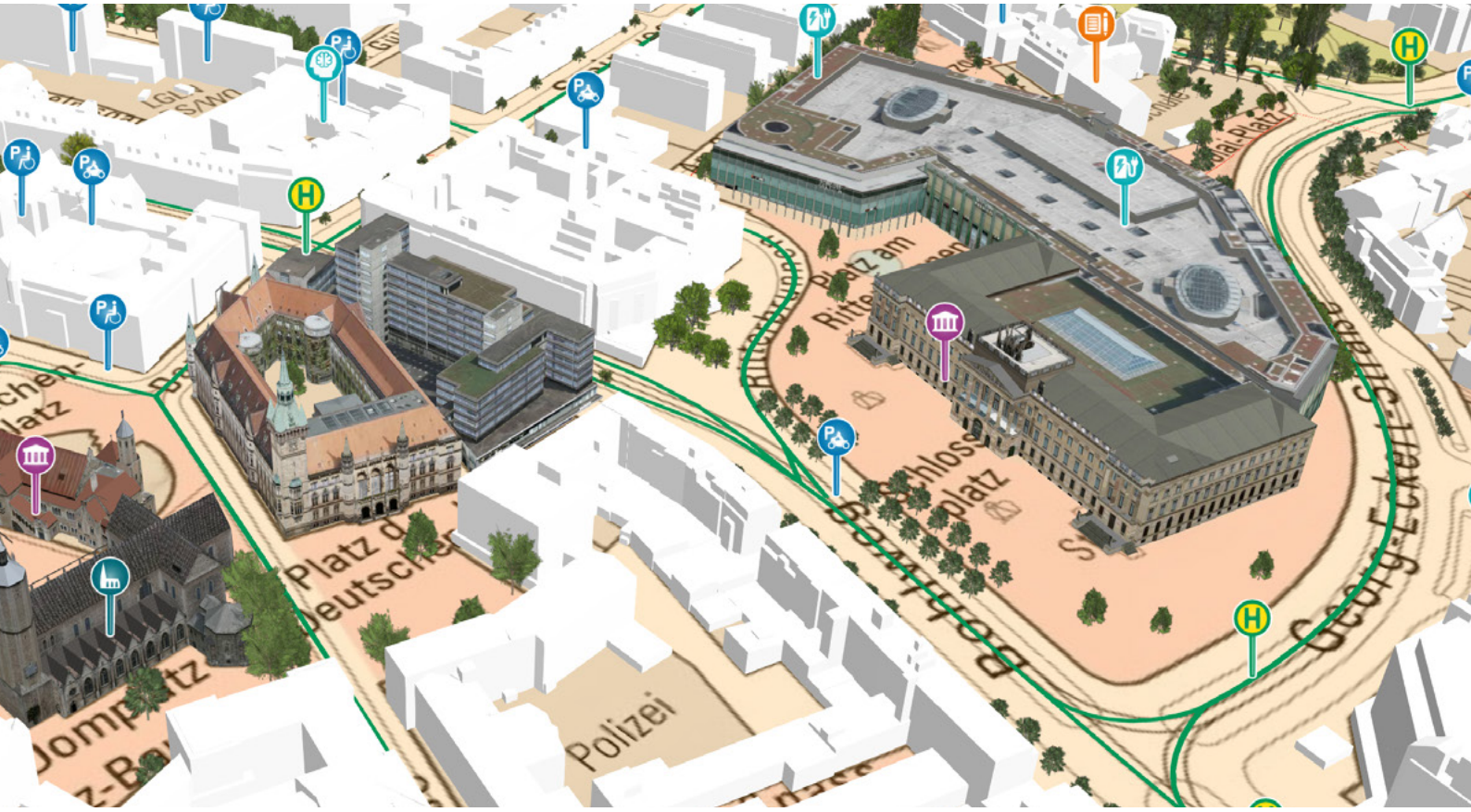
The goal of the joint project is requirements elicitation and customized design of an urban data platform and an urban data twin for the city of Braunschweig. The main project components of Fraunhofer IESE lie in the requirements elicitation, inventory, and conceptualization phase, which is being conducted jointly with PD, but especially in the implementation of a so-called proof-of-concepts (PoC) for UDP and UDT.

Use case: construction projects and their impact on the urban climate

The first step after the requirements workshops will be the selection of a suitable use case for the PoC from the municipal fields of action. As a valid concept demonstrator, the prototype must be able to show the strengths and advantages of an urban data platform and demonstrate the ability of a data twin to answer "what-if" scenarios, for example by means of simulation. In the current project phase, a decision has not yet been made for the specific use case, but it is still worth taking a look at one of the possible variants:

New construction projects – especially the major ones – should be assessed in advance for their potential impact on urban climate. Until now, the only option has been to carry out an externally tendered climate simulation. This is a bureaucratic, lengthy and expensive procedure that is too time-consuming for small and medium-sized construction projects. Furthermore, this procedure does not allow for iterative planning loops involving suggestions for improvement with the participation of other departments of the city administration.

On the other hand, it would be desirable to use a digital process to independently carry out climate simulations for new construction projects in the urban area. In this case, a prototypical urban data platform would enable the sharing and transfer of data between the various departments, such as building, environmental and green space authorities, and the control of

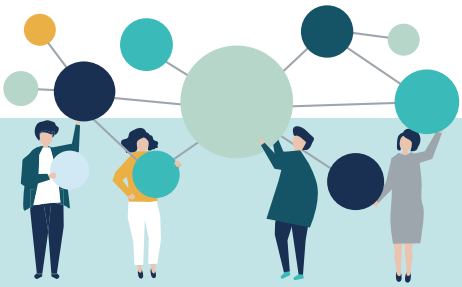


With the 3D basic twin, the city of Braunschweig already has a powerful infrastructure.

the digital process. An urban "climate twin" based on open source software would carry out the complex simulation calculations and visualize the results in a 3D representation of the city. Iterative planning loops involving various specialist areas would thus be possible. However, whether this use case can be fully or partially implemented as a PoC as part of the project still needs to be examined in consultation with the specialist departments and technology suppliers involved.

Creating the conditions for the Digital Ecosystem

Parallel to the development of the PoC, PD and Fraunhofer IESE are developing an overall concept for the UDP and other "specialized twins" of the UDT in close cooperation with the city of Braunschweig. To this end, unmet data needs, relevant use cases and any necessary organizational changes must be identified for the requirements identified. The aim of these analyses is to develop suitable processes that serve as the basis for the operations of urban data platforms and data twins. The totality of these requirements and processes provides the prerequisite for the consolidation of a target architecture of the Digital Ecosystem, from which concrete technologies and infrastructures can be derived.



Spread Smart City and Smart Region solutions widely

The "DEUTSCHLAND.DIGITAL" marketplace developed by Fraunhofer IESE is part of the new step-by-step plan "Smart Cities and Regions" of the Federal Ministry of Housing, Urban Development and Construction (BMWSB). This is intended to create a framework for the digitalization of cities and municipalities in Germany and support them in implementing digital solutions.

Further information about the marketplace:
www.deutschlanddigital.org/

Click here for the step-by-step plan:
s.fhg.de/stufenplan-bmwsb

3 questions for...

...Dr. Nora Reinecke, who has been project manager of the cooperation project Connected Urban Twins (CUT).

As a partner in the consortium of the Coordination and Transfer Office Smart City (KTS), Fraunhofer IESE jointly supports the "Model Projects Smart Cities" in shaping digitalization in the sense of integrated, sustainable urban development oriented toward the common good. IESE is particularly active in digitalization topics such as urban data platforms, urban Digital Twins, city apps and open source.

Dr. Nora Reinecke is the lead coordinator of a cross-city and cross-departmental project team that is driving the further development of urban data platforms and Digital Twins in the cities of Hamburg, Leipzig and Munich. We asked her personally how urban Digital Twins can drive forward sustainable urban development.

1 What is your vision of a Smart City?

My vision of a Smart City is a sustainable, livable and future-proof city that is supported by urban data platforms and urban Digital Twins. Using innovative digital technologies and applications, we can create digital images of the city to simulate "what if" scenarios for various urban development issues.

"Digital Twins of cities are more than just 3D models!"

By linking different data sources and integrating citizen participation, complex urban developments can be better understood and managed. Our three project cities Hamburg, Leipzig and Munich are also setting new standards for inter-municipal cooperation and knowledge sharing by jointly developing replicable and customizable solutions for Smart Cities.

2 What do you think of the statement: "Digital Twins of cities are more than just 3D models"?

I absolutely agree! Urban Digital Twins not only include the three-dimensional visual representation of the physical city, but also have access to extensive urban data from various sources via urban data platforms that develop scenarios with dynamic and interactive models. These models make it possible to simulate and analyze complete urban processes, which contributes to improved planning and decision-making. Urban Digital Twins therefore go far beyond mere visualization. They are to be understood as tools for integrated urban development and the participation of urban society – our focus in the CUT project. In addition, there are many other areas such as mobility, social infrastructure, environmental and green planning, to name but a few.

3 How can urban Digital Twins contribute to a sustainable city of the future?

As tools for planning, monitoring and optimizing urban processes, urban Digital Twins can make a significant contribution to the sustainability of cities of the future. By integrating and analyzing real-time data, they enable a more precise use of resources, for example by optimizing energy consumption and improving traffic flows, which leads to a reduction in emissions and congestion. By combining socio-economic indicators and structural and infrastructural information, urban development and displacement processes can be anticipated, monitored and controlled.

Urban Digital Twins support the development of sustainable infrastructure projects by simulating the effects of different scenarios on the environment and thus promoting well-founded decisions. Last but not least, they contribute to strengthening citizen participation by providing transparent and accessible data that enables citizens to actively participate in shaping their city. Urban Digital Twins can also contribute to the resilience of cities by identifying potential risks at an early stage and supporting the planning of emergency measures.

In summary, urban Digital Twins are not only innovative tools for a wide range of applications in integrated urban development, they also pave the way for sustainable and future-proof cities.

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