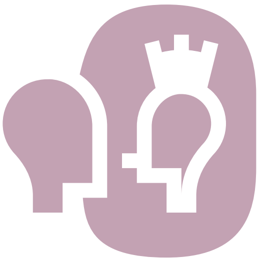
For people with prosthetic limbs, brain-computer interfaces (BCIs) promise to translate brain activity into control signals.



Comprehensive sensor technology records a multitude of data during the nearly 90-minute race and sends it to the computers at the company's headquarters some 80 miles away in Woking. Enriched with additional data – weather and temperature, for example – a digital twin of the race car is produced, a virtual representation in the real-life racing situation that provides prospective analyses. In collaboration with the University of Oxford and the consulting firm Deloitte, McLaren has been using digital technology for some time. "We've been doing this for 20 years and have created a digital model of the race car, a digital twin, but we don't use that term," explained Dr. Caroline Hargrove, CTO of McLaren Applied Technologies, in an interview.

## NO CLEAR DEFINITION

A Google search for the German "digitaler Zwilling" currently returns 2.3 million hits, yet "digital twin" gets 316 million. Curious: most of them are in German. "The term is largely unused in the English-speaking world," verified Damian Bunyan, Briton and CIO of the global energy company Uniper (see page 30).

That there remains to this day no uniform, binding definition of "digital twin" can quickly lead to misconception. "Many entrepreneurs think they have a digital twin just because they created a digital model of their products or production," said Dr. Kai Lindow from the Fraunhofer Institute for Production Systems and Design Technology. But that is not exactly a digital twin.

The virtual representation of a product or process that is fed with real data – this is the generally accepted definition. "For a digital twin, there has to be a digital master and a digital shadow," clarified Lindow. The master would be something like a digital geometric model or, very generally, the master data; the data obtained over the lifecycle of a product or system would be the digital shadow. "If you put both together, you get the digital twin." Different definitions focus on different aspects. What is undisputed, however, is that the twin is a comprehensive application for product lifecycle management (PLM) – with enormous potential. Such as developing entirely new business models. "Working out the specific application area for one's own digital twin and focusing on one's own issues plays an important role," emphasized Uwe Weber, head of the Industrial IoT Center at Detecon, the consulting subsidiary of T-Systems. What processes are in the spotlight? What use cases does a company want to implement? What data is relevant for it? And how can sensor and operating data dovetail with business processes?

Let us take as an example the concept of "building information modeling" (BIM). This cooperative industrial method is based on digital models of buildings on the basis of which all information and data relevant to their lifecycle are consistently recorded and managed. The goal is transparent communication between all involved to advance them for further/progressive processing. Aside from builders, owners or operators, this also makes it possible for building management – an industry with a turnover of over € 15 billion in Germany alone – to use an integrated, closed flow of information for sustainable and professional maintenance. From project planning and development to building preparation, implementation and documentation, to building operation. “Specifically, BIM-assisted simulations and analyses in the form of a digital building twin would already enormously facilitate the planning and steering of the construction process, the coordination of trades and virtual construction progress monitoring to standard,” explained Weber further. Whether in buildings or systems, machines or equipment according to the consulting firm Gartner, digital twins will exist for billions of things through 21 billion connected sensors and interfaces by 2020. And the digital association Bitkom estimates that the sum of all digital twins will be responsible for a productivity increase of € 78 billion by 2025 in the German manufacturing industry alone.

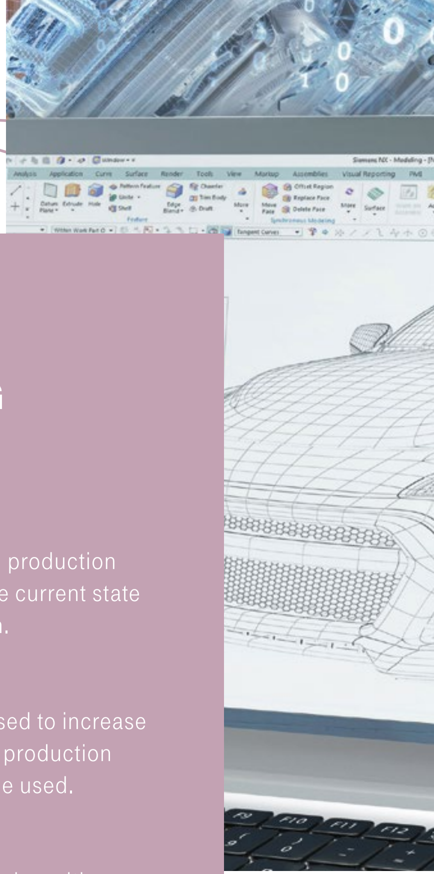
## VERSATILE APPLICATIONS

The digital twin was first described by American Michael Grieves at the University of Michigan in 2002 (see page 14). Yet only modern technologies have allowed the concept to expand its potential: big data applications, IoT, the cloud and sensors. NASA was one of its first adopters: While developing a robot to be used on Mars, NASA combined a model with real data from the Red Planet. However, the digital twin has been out of the exotic spheres of space technology for some time and has come to industry, at least as a vision. The possible applications are extensive (see box). The technology can realize its full potential in combination with applications when, for example, the data from production monitoring is used as input for virtual start-up. Or when quality management finds the causes of known defects in the digital twin and the parameters for future production are then modified accordingly.

Ultimately, the continued networking between these applications could lead to a bidirectional system where the digital twin provides feedback to its physical brother – resulting in a self-controlling system. “Technically, that’s definitely feasible,” confirmed Lindow. “However, for that it would be necessary to enrich the model with artificial intelligence and machine learning.”

## LITTLE USE IN PRACTICE

Where are digital twins already being used in industry? “It’s not yet happening nationwide,” said Lindow. “I have the feeling it’s still being researched in most companies.” For a field test, his institute worked with a scooter sharing service provider. The scooters were outfitted with sensors,



## MULTI-TASKING

- **PRODUCTION MONITORING**
  The data continuously collected from production creates a comprehensive image of the current state of the production system in operation.
- **PRODUCTION OPTIMIZATION**
  Analysis of production data can be used to increase efficiency. Comparison with a similar production system at another location can also be used.
- **PREDICTIVE MAINTENANCE**
  By reviewing historical data or comparing with a similar production system, it is possible to calculate upcoming failure in components and wear parts.
- **QUALITY MANAGEMENT**
  Continuous monitoring of product quality offers clear advantages over random inspection.
- **REORGANIZATION**
  Conversions of production to other products or smaller series (keyword: customizing) can be run through first in the digital twin.
- **SYSTEMS PLANNING AND VIRTUAL START-UP**
  Analysis of historical comparative data makes it possible to predict the performance of a system that has not yet been constructed.
- **LOGISTICS PLANNING**
  Optimization of the supply chain can result in significant increases in efficiency, especially for just-in-time or just-in-sequence production.
- **PRODUCT MONITORING**
  Product lifecycle management is relevant for capital goods especially. Even for the end of life of a product, it can be interesting to know what materials are in the product to facilitate recycling.
- **PRODUCT DEVELOPMENT**
  Virtual simulations help with development. Data collected from the use of a product can also help develop and improved version (design feedback).


Luxury sports car maker Maserati used digital twins to slash the design time for new car models in half.

so the use of every vehicle could be documented. Where was it checked out? Where was it checked back in? How far did it travel? And what rate was paid? This made it possible to compile a detailed analysis of individual users and the entire fleet, which may even make it possible to adjust the price structure and battery charging times. According to Lindow, the application is used at best in subfields. One example is logistics: At Airbus, digital twins help coordinate the 12,000 partners supplying the three million parts that make up an A319. Another is product development: In automobile development, engineers test load scenarios for individual components or entire vehicles, down to a virtual crash test. Fiat Holding's sportscar manufacturer, Maserati, has used this to cut the development time of its vehicles nearly in half.

"Digital twins have an effect on the business model," explained Lindow. That hinders its adoption. If a machine manufacturer, for example, realizes its customers want to buy the machine capacity but not the machine itself, does it then become simply a service provider?

Lindow emphasized that the adoption of a digital twin also needs to be preceded by an extensive analysis. "I need to be clear about what I want to achieve with the twin and where the business value is." Does my system already have sensor technology? How much data do I need? Is real-time monitoring necessary or is the data collected at specific points in time adequate? In the end, sensors, data transmission and data analysis are not free. Lastly, a company needs to look at what data outside of production could be relevant. For a company that maintains aircraft turbines, it could be interesting not only to know how many flight hours a turbine has on it, but also what routes they flew. This is not obtained from the airline's data, but from a third party, such as a flight tracker. "At the end of the day, aircraft flying primarily over the Sahara are exposed to entirely different loads than those flying over the Atlantic," added Lindow. For the same reason, automobile manufacturers prefer to test their prototypes in wastelands – whether in the Arctic Circle or Death Valley. Considering the demands of those locations by dust, sand and co., the Formula 1 cars have it much easier – they always drive on hard asphalt.

**"For a digital twin, there has to be a digital master and a digital shadow."**

**DR. KAI LINDOW,**
Fraunhofer Institute for Production Systems and Design Technology

bestpractice@t-systems.com
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