Extract from the Annual Report 2021
To the website: https://www.ist.fraunhofer.de/en.html

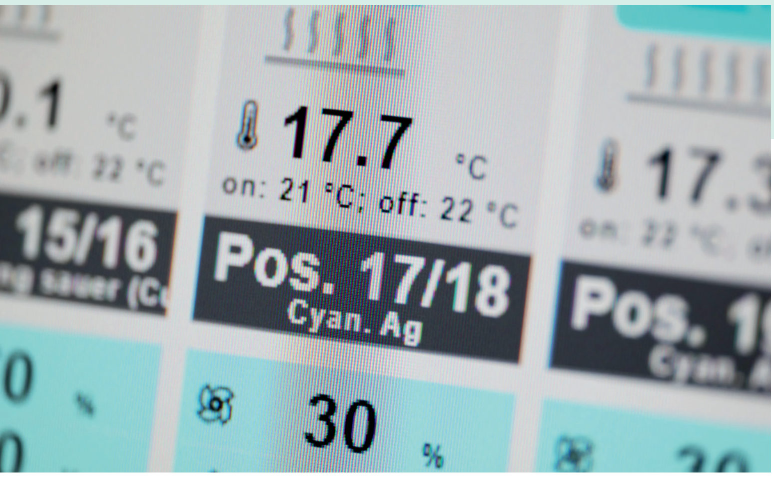
In focus: Digitalization in surface technology

In surface technology, both quality requirements and cost pressure are increasing constantly. In addition, as a study commissioned by the German Federal Ministry for Economic Affairs and Climate Action (BMWK) determined, the complexity of the products[1] is continuously increasing, as a result of which the demand for technical expertise is also becoming ever greater. One approach to providing the required extremely extensive knowledge base – at least to some extent – is a digital twin, in which relevant process and product properties are represented by simulation models. With a real-time capable digital twin, the possibility also exists to react quickly and predictably to, for example, production fluctuations or new product requirements.

Up to now, simulation has been based primarily on phenomenological, i.e. physical and/or chemical models, in which, however, the process and product properties are often incompletely reproduced or which require considerable computational effort. Data-driven models based on characteristic diagrams or methods of artificial intelligence (AI) – in particular, deep learning – can circumvent this problem.

Aside surface technology, AI-based methods are already being used successfully for web searches, recommendation systems, image recognition, speech recognition and text generation. In order to also be able to use AI in surface technology, cross-product and cross-process databases must be constructed in which process data is collected in-situ and the results of downstream sample and product analytics are integrated accordingly. The data forms the foundation for digital twins trained on the specific products and processes, consisting of a combination of simplified physics-based models with AI methods.

By means of the digital twins, production processes can be controlled and optimized on the basis of models and required maintenance can be predicted. Quality, throughput and reproducibility of coating processes in surface technology can therefore be improved, whilst the impact on the environment is simultaneously reduced.



The visualization of the process data plays a central role in digitalization.

[1]Bischoff, J. ; et al.: Erschließen der Potenziale der Anwendung von Industrie 4.0 im Mittelstand. Mülheim an der Ruhr: agiplan, 2015, XIV, 386 S.

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"The digital transformation and, in particular, approaches using artificial intelligence methods are drivers for modular, flexible and scalable production systems and form the focus of current work at the Fraunhofer IST."

Prof. Dr.-Ing. Christoph Herrmann / Director

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Employees of the Fraunhofer IST discuss the current process parameters.

Implementation strategy for a data-mining project

The CRISP-DM model (Cross Industry Standard Process for Data Mining) is a standard model for data mining that is widely used, cross-industry and publicly available. This model was developed around 1996 by renowned companies and offers a very good possibility for the meaningful mapping and processing of data-mining projects. The model, which we also use for orientation in our digitalization projects at the Fraunhofer IST, is divided into six phases, whereby individual process phases can also be run through repeatedly. The individual phases are described briefly below, and are illustrated using projects at the Fraunhofer IST as examples.

"Central data collection offers the opportunity to evaluate data and identify correlations. By digitalizing our processes, we are fulfilling the prerequisites for the implementation of artificial intelligence."

Dipl.-Phys. Holger Gerdes / Scientific Assistant

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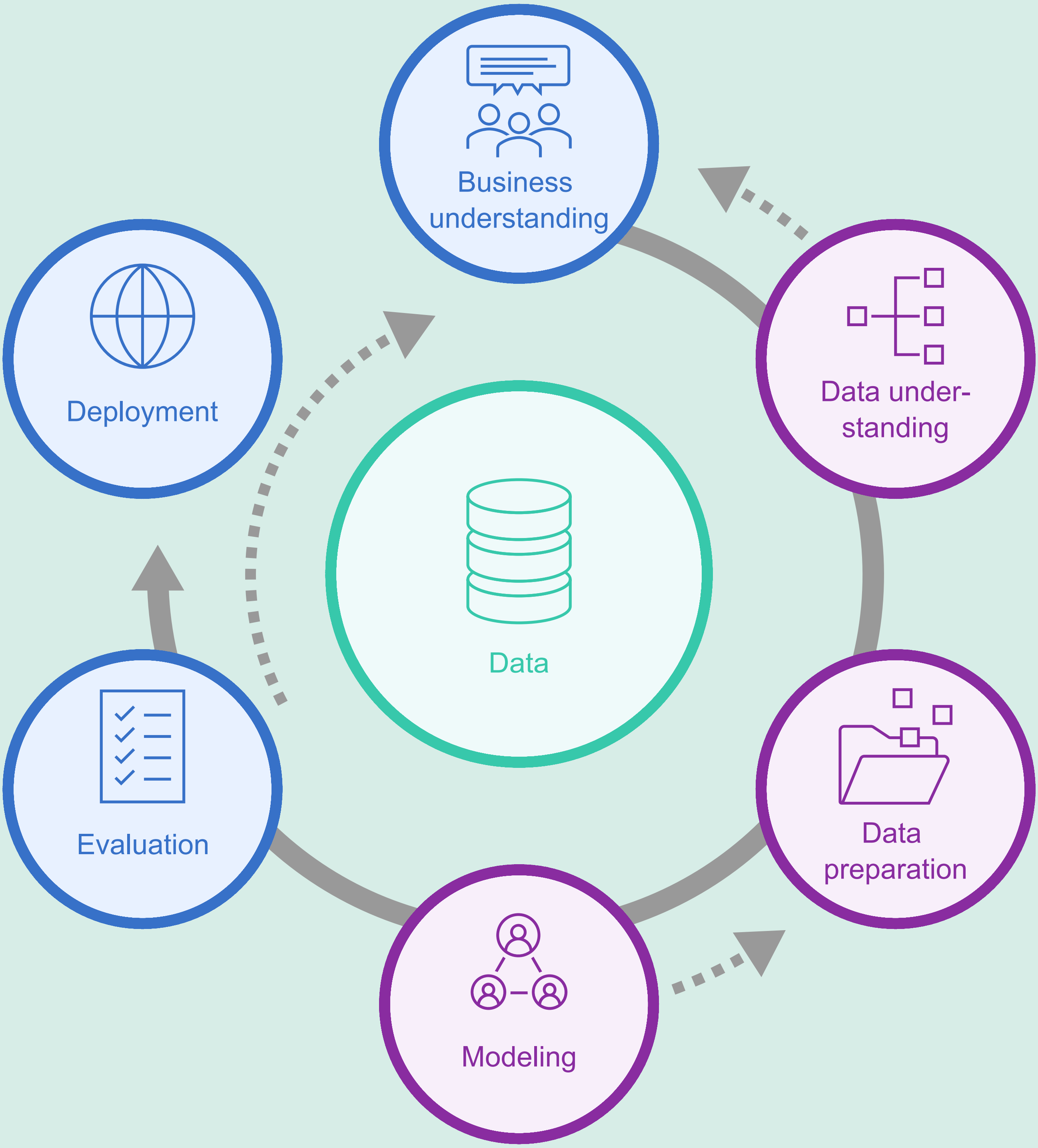

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Phase 1: Understanding of business

The first phase of CRISP-DM is a fundamental requirement for the successful completion of the project. In this phase, the objectives and requirements of the data mining are defined. The objective should hereby be **"smart"**, i.e. "**s**pecific, **m**easurable, **a**ccepted, **r**ealistic and **t**imetabled". This is essential if it is to be possible to determine, after completion of the project, whether the data mining has really been successful.

With its decades of experience and more than 200 employees, the Fraunhofer IST can look back on outstanding expertise in the field of coating and surface technology and has already implemented numerous digitalization projects. The focus has hereby been directed at a wide variety of issues. One example is the integration of commercially available environmental sensors on the basis of Message Queuing Telemetry Transport (MQTT) via Wi-Fi for the recording of room temperature, air humidity and air pressure, in order to automatically store the aforementioned parameter databases and to automatically inform employees via E-Mail when threshold values are exceeded or not achieved.

Phase 2: Understanding of data

In the second phase of the project, the project objective is compared with the existing data sets. In this phase, a decision is to be made as to whether the data sets are sufficient for achieving the project objective with a good chance of success. If all necessary data are available, the next phase can begin. If the data situation is not sufficient, either the project objective must be redefined or the data must be subsequently entered or collected.

For this purpose, the Fraunhofer IST relies, amongst other things, on Open Platform Communications Unified Architecture (OPC-UA) servers for data provision. These servers have already been implemented in new plant acquisitions, and have also been successfully retrofitted in existing plants. They enable the automated recording and backup of process parameters.

The data is saved in central databases which also contain additional information, e.g. regarding the laboratory environmental conditions, temperature, humidity and air pressure. Furthermore, web pages are made available to employees at the Fraunhofer IST as an upload front end. These upload pages accept practically any document format and also store them in databases in prepared form.

Phase 3: Preparation of data

After completion of the first two phases, it must be ensured that the data are suitable for the project objective and can now be prepared for the subsequent process. The objective of the third phase is to provide modeling with a data set containing all necessary, correctly formatted values. In order to achieve this, the often different data sources must be merged, errors in the data sets suitably corrected and, if necessary, new variables developed.

For this purpose, the Fraunhofer IST has, for example, developed software tools which make it possible to automatically divide large microscope images into smaller units, to adjust them in terms of brightness, contrast and color space and, furthermore, to provide the file name with additional information. If required, data processing can be performed within databases. For this, new tables are created, which contain the agglomerated information.

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Phase 4: Modeling

In the modeling phase, a suitable method for solving the problem is sought. The possible methods encompass the utilization of simple statistics, semi-empirical models or machine-learning algorithms right through to neural networks.

At the Fraunhofer IST, machine-learning algorithms are applied in cooperation with partners for the prediction of layer properties and process parameters, and neural networks are used in image recognition.

Phase 5: Evaluation

In the modeling phase, solely the model is tested. In the evaluation phase, the aim is to test the entire processing routine and to clarify whether the process from data acquisition through processing and modeling functions reliably. These so-called pipelines should also be robustly tolerant of errors such as the omission of data.

Phase 6: Deployment

In the final phase, the project is integrated into the company processes. All digitalization projects developed at the Fraunhofer IST are prepared in Docker containers and can therefore also be ported very easily to other systems.

Glossary

Data mining

Many processes in surface technology are very complex and correlations between different process parameters are often not directly recognizable. Data mining provides support in identifying trends and interrelationships by applying statistical methods to the data sets. The term "data mining" is somewhat misleading in this context, as it does not involve generation of the data itself, but rather the acquisition of knowledge.

MQTT

Message Queuing Telemetry Transport is an open network protocol used for communication between machines.

OPC-UA

Open Platform Communications Unified Architecture is an industry standard for platform-independent data exchange.

Structured and unstructured data

Structured data, in contrast to unstructured data, have a predefined and formatted data structure. Examples of structured data are credit-card numbers, addresses, barcodes and, in particular, relational databases. Unstructured data are mainly texts such as E-Mails, presentations, reports, videos and images.

Kontakt

Dipl.-Phys. Holger Gerdes
Phone +49 531 2155-576
holger.gerdes@ist.fraunhofer.de

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