Fraunhofer ILT

Fraunhofer Institute for Laser Technology ILT

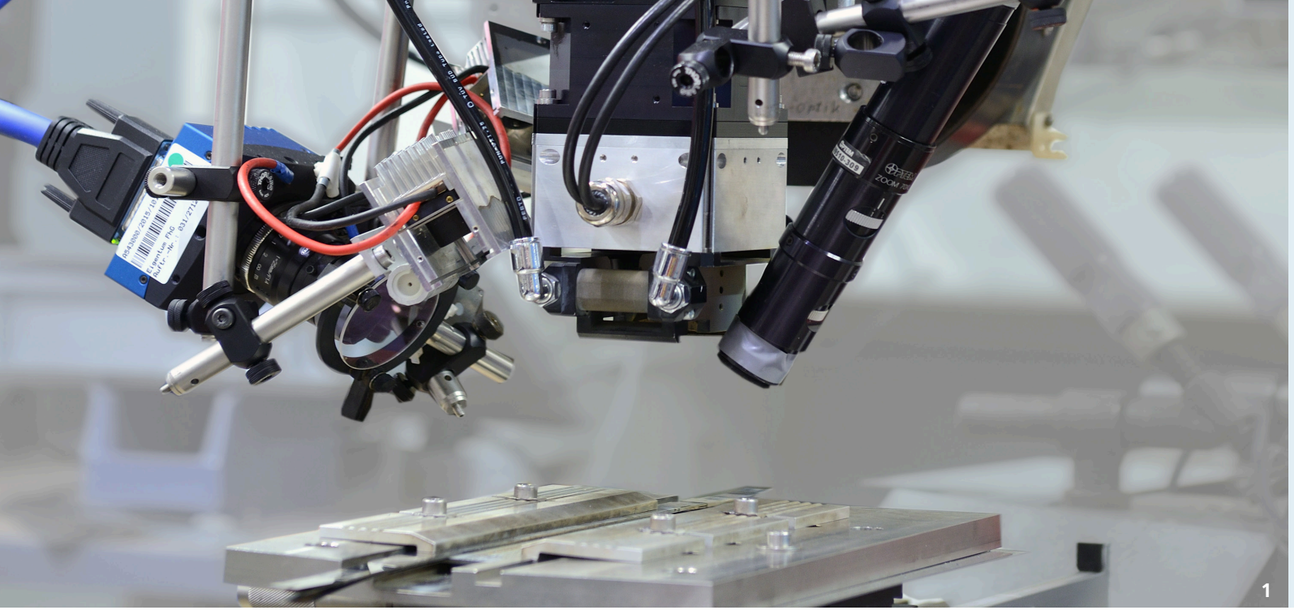
Artificial Intelligence in Laser Material Processing

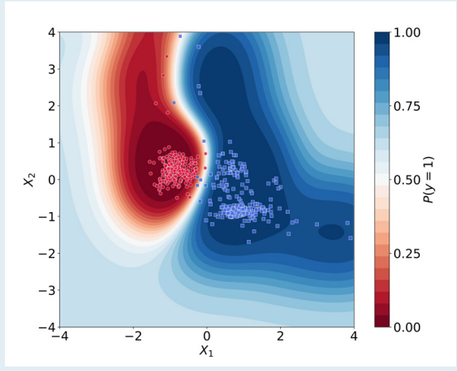
As machine and production lines are increasingly become networked and digitalized within the Fourth Industrial Revolution, the volume of product-related data volumes will grow significantly. This, in turn, will unlock enormous potential to improve quality assurance and to optimize production processes. The Fraunhofer Institute for Laser Technology ILT aims to harness this potential by using algorithms from the field of machine learning, one goal of its research and development in process sensor technology.

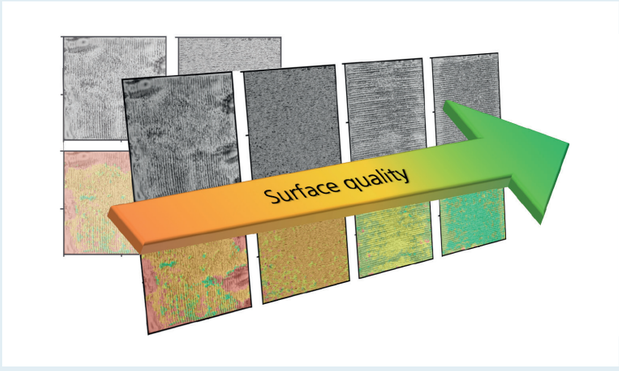
AI-based quality monitoring in real-time

Depending on the application and the machining process, different sensors, signals and data streams can be used to develop real-time AI-based quality monitoring. For example, in-situ process monitoring using high-speed thermal imaging allows users to capture the interaction zone of a laser welding process in detail. Combined with machine learning (ML) methods, this monitoring technique makes it possible to identify different seam and process imperfections.

AI solutions can be used, for example, for real-time control of laser processes.







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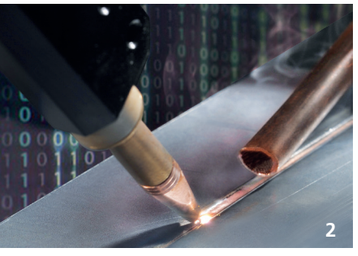

1. Multi-camera test setup for laser beam welding process.
2. Laser brazing process for automotive applications.

To advance application-specific AI solutions, the experts at Fraunhofer ILT have developed their own software module. Among other things, this tool enables them to calculate and evaluate different signal and image features, which are then combined to form an overall process fingerprint. In a further step, the institute can carry out a quality assessment of the process result to generate carefully prepared sample data sets.

Depending on the specific application, different ML algorithms are used to distinguish process imperfections – such as surface pores, seam collapse, lack of connection, spatter and deviations in focal position – on the basis of the specific fingerprint.

In addition to algorithms found in classical machine learning, deep learning approaches such as convolutional neural networks (CNN) are used at Fraunhofer ILT to assess local weld seam quality based on raw image data. This offers great advantages, for it is not only more flexible, but can also scale up the AI solutions since here, for example, complex FPGA implementations of the image processing steps can be omitted. In many cases, such end-to-end solutions can also detect defects significantly better than conventional ML approaches; this way, high detection rates can be achieved along with low false alarm rates. After appropriate runtime optimization, the trained neural networks can be executed on commercially available GPUs at over 1000 frames per second with low latency, making them suitable for real-time quality monitoring in laser material processing.

Process optimization with AI

In addition to pattern recognition, AI can also increase the efficiency and improve the quality of laser material machining processes. In practice, it has been shown time and again that different influencing variables lead to unwanted deviations from the planned machining process. To compensate for such process deviations, conventional control systems are often unable to handle the complex interaction mechanisms in laser material processing, owing to assumptions made during the design phase. Machine learning methods can provide a remedy, for example, by having a software agent learn an optimal strategy for meeting the defined process goals based on real measurement data or simulatively generated data.

To this end, Fraunhofer ILT has developed an AI-based solution for laser powder bed fusion (LPBF), which, in a first step, evaluates the surface roughness of LPBF components based on corresponding camera images. In a further step, methods from the field of reinforcement learning (RL) are used to enable the software agent to learn an optimal strategy to set the process parameters for the next component layer. Based on the surface image data, the software agent learns to select the process parameters that result in the lowest possible surface roughness and in a minimum number of surface defects. This solution allows the software agent to automatically and continuously adapt the learned strategy to new process situations and target parameters.

In principle, the process can be transferred to other machining processes. It can used for multi-criteria optimization as well as for the real-time control of a process.

Advantages of AI for your application

The existing solutions can be flexibly adapted to individual customer requirements thanks to their open software architecture. At Fraunhofer ILT, an NVIDIA DGX station with a performance of 480 TFLOPS is available, in addition to GPUs and FPGAs in the form of embedded systems, for analyzing large amounts of data and developing AI solutions.

3. Visualization of the decision boundaries of a classification algorithm for the detection of process defects (red: process defect; blue: process OK).
4. Optimization of surface roughness of LPBF components using AI.

The advantages at a glance

- Utilization of savings potential through optimized process parameters
- Utilization of different multidimensional data streams from production
- Saving of cost-intensive downstream quality assurance processes
- Fast adaptation of the system to changed boundary conditions through automatable re-training

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Fraunhofer Institute for Laser Technology ILT

The Fraunhofer Institute for Laser Technology ILT is one of the most important development and contract research institutes in laser development and application worldwide. Its activities encompass a wide range of areas such as developing new laser beam sources and components, laser-based metrology, testing technology and industrial laser processes. This includes laser cutting, ablation, drilling, welding and soldering as well as surface treatment, micro processing and additive manufacturing. Furthermore, Fraunhofer ILT develops photonic components and beam sources for quantum technology.

Overall, Fraunhofer ILT is active in the fields of laser plant technology, digitalization, process monitoring and control, simulation and modeling, AI in laser technology and in the entire system technology. We offer feasibility studies, process qualification and laser integration in customized manufacturing lines. The institute focuses on research and development for industrial and societal challenges in the areas of health, safety, communication, production, mobility, energy and environment. Fraunhofer ILT is integrated into the Fraunhofer Gesellschaft.

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