Hand in hand - The evolution of AI from assistant to decision-maker

Artificial intelligence (AI) aims to increase the efficiency and effectiveness of industrial processes. Ultimately, this should reduce production costs and production time, improve quality and increase the robustness of industrial processes.

AI in automated optical and X-ray inspection in the electronics industry

The call for more flexible and autonomous automation will become louder and louder - due to increasing demands on product variety, process flexibility or higher costs. This is especially true for the inspection systems that are standard in modern production lines. It is certain that AI is an important factor in this process of change. But where exactly are the potential uses of AI-based methods in the domain of automatic inspection systems? Among other things, the focus is on manual processes such as the creation of inspection programmes or the classification of defects at the verification station, as the cost aspect quickly comes into play there. With this in mind, the software of the AOI systems from GOEPEL electronic was expanded at an early stage to include an AI-based expert system for automated test programme generation. With the software module "MagicClick", test programmes are created and optimised fully automatically. The special feature: without any library entry, a production-ready test programme including component library is generated in just a few minutes. The parameters are also adjusted completely automatically, even taking into account real process fluctuations.

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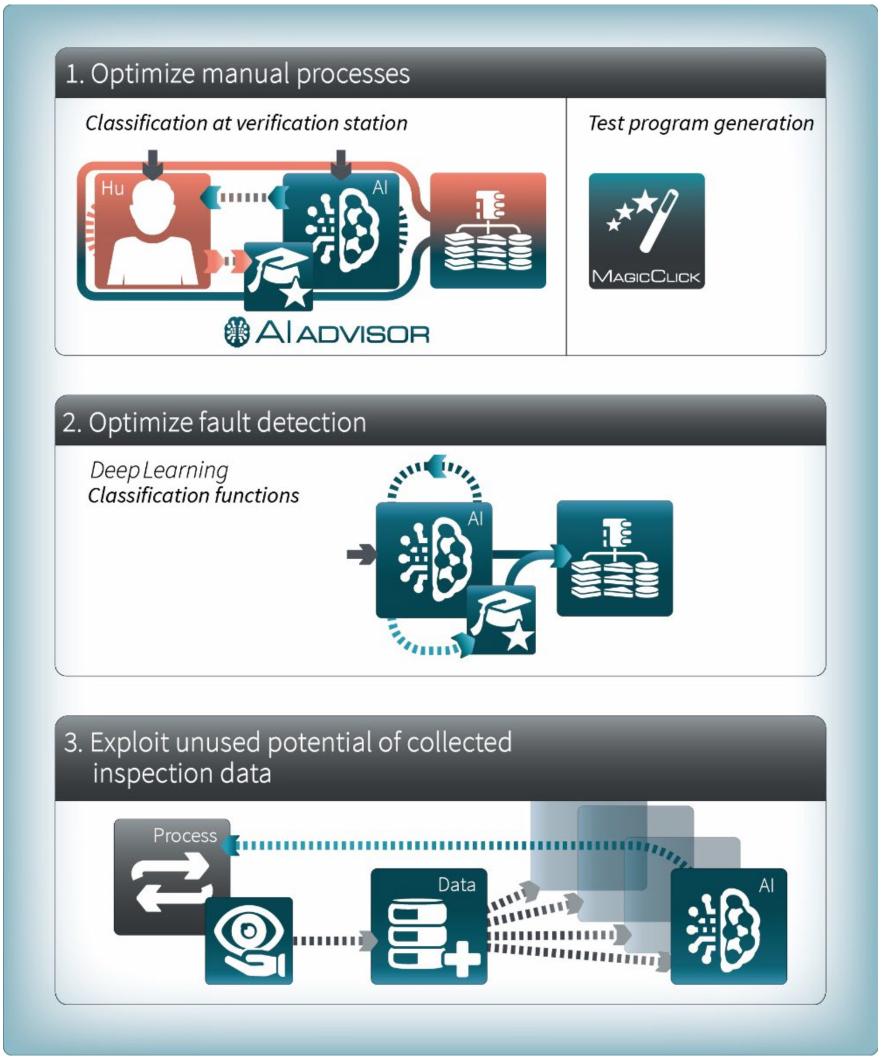

Fig. 1: Potentials for the use of AI-based methods in the domain of automatic inspection systems.

The transformation of AI from assistant to decision-maker

Both in production lines for electronic SMD assemblies ("Surface Mounted Devices") and in THT production lines (Through Hole Technology), automatic optical inspection or automated X-ray inspection is part of the standard processes for quality assurance. The corresponding inspection systems test the assemblies 100% for correct placement and soldering of the components and defective assemblies are sorted out. In the case of rejected assemblies, it is typical that the defects detected by the inspection system are finally evaluated and classified by human eyes at a verification station. This visual assessment is a monotonous activity and carries the risk of errors due to fatigue and human error. The danger of wrong classification decisions is increased when complex defect patterns have to be assessed with changing process parameters. Wrong decisions are fatal when an

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AOI or AXI system has detected an actual defect and this defect is subsequently classified as a "pass". In this case, we speak of a false-positive classification, which in turn is equivalent to a slip. The defective PCB would be processed further and in the worst case (if the subsequent electrical tests also do not lead to failure) would be delivered to the customer.

This is where the AI advisor software module, newly developed by GOEPEL electronic and integrated into the PILOT Verify verification software, comes in. For each error detected by the AOI or AXI, the AI-based function forms its own decision. In a first stage (Level 1), an assistance function is provided with this additional information. When the operator has made his decision, there are two independent opinions for each error found, analogous to a four-eye principle - that of the operator and that of the AI. If the AI comes to a different conclusion than the operator, a message is displayed and the user is asked to review his decision again.

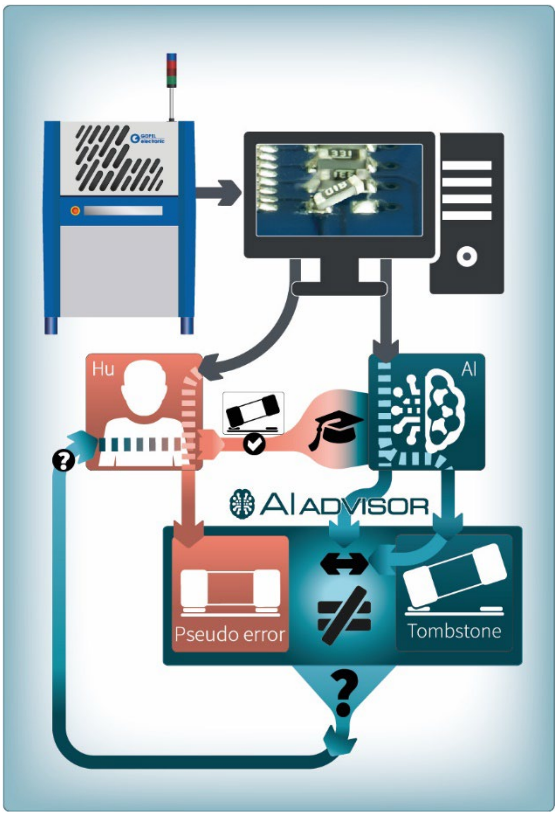

Fig. 2: AI advisor

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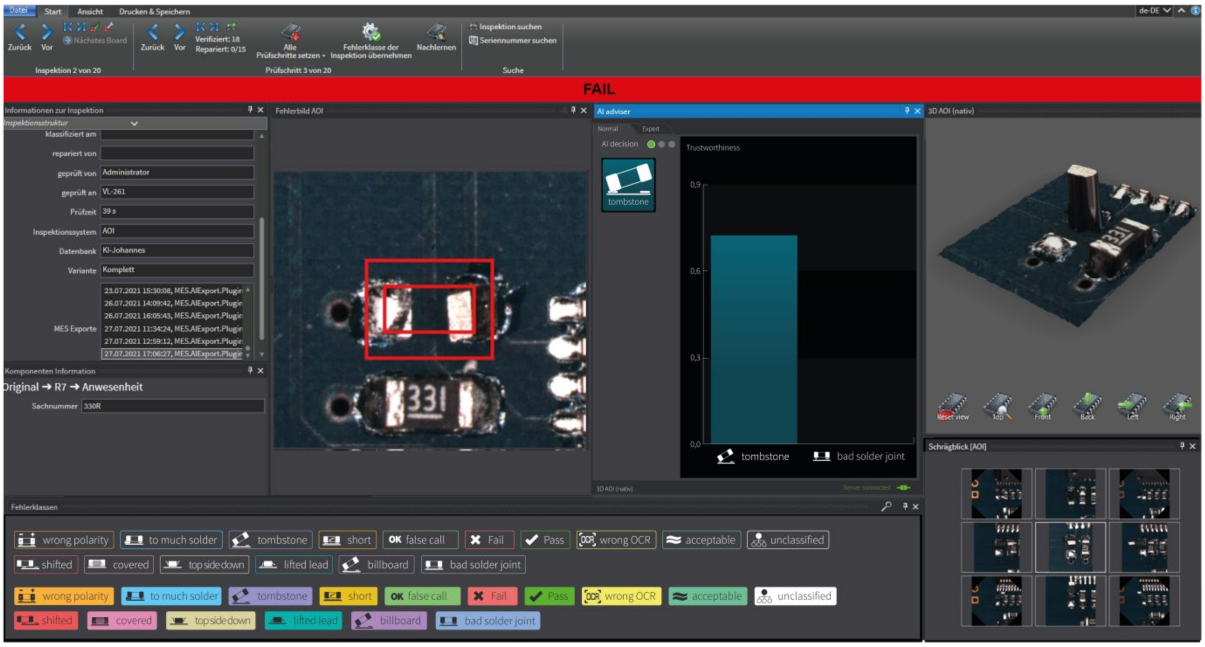

Fig. 3. Screenshot of the Pilot Verify software with AI advisor.

The assistance function of the AI advisor realised in the first stage (Level 1) ultimately ensures that incorrect decisions are prevented during defect verification and that no detected defects are subsequently classified as "pass". By constantly adding further relevant training data during operation and the subsequent training processes, the AI becomes better and better at making classification decisions. In level 2, the artificial intelligence is then trained to such an extent that all possible error situations are reliably recognised and verification can take place automatically. The artificial intelligence then makes the basic decision and classifies the occurring errors independently. Verification by the operator is only necessary in exceptional situations, namely when the AI cannot make a safe classification decision. The automated classification of almost all faults in level 2 significantly reduces the workload of the operators at the verification stations.

Good training as a basis

The application of Deep Learning (DL) is not limited to the pure development of an AI model. For an industrial application of DL methods, the creation of a balanced and valid training database is essential. This training database should also be permanently expanded during the life cycle with significant examples from ongoing production.

The concept of the AI advisor is accordingly flexible. On the one hand, it is possible to start with an already predefined database after installation, which is retrained during operation with further image

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data from the corresponding user decisions. On the other hand, a model can also be trained without a predefined database only on the basis of classification decisions historically stored in the database of theinspection system. In this case, too, after the initial training, further image data from the corresponding user decisions, which are available in productive operation, are used to retrain.

In productive operation, the AI software receives inspection data from the inspection system, assigns the inspection data to the respective AI model instances, performs the inference and transmits AI decisions to the verification software.

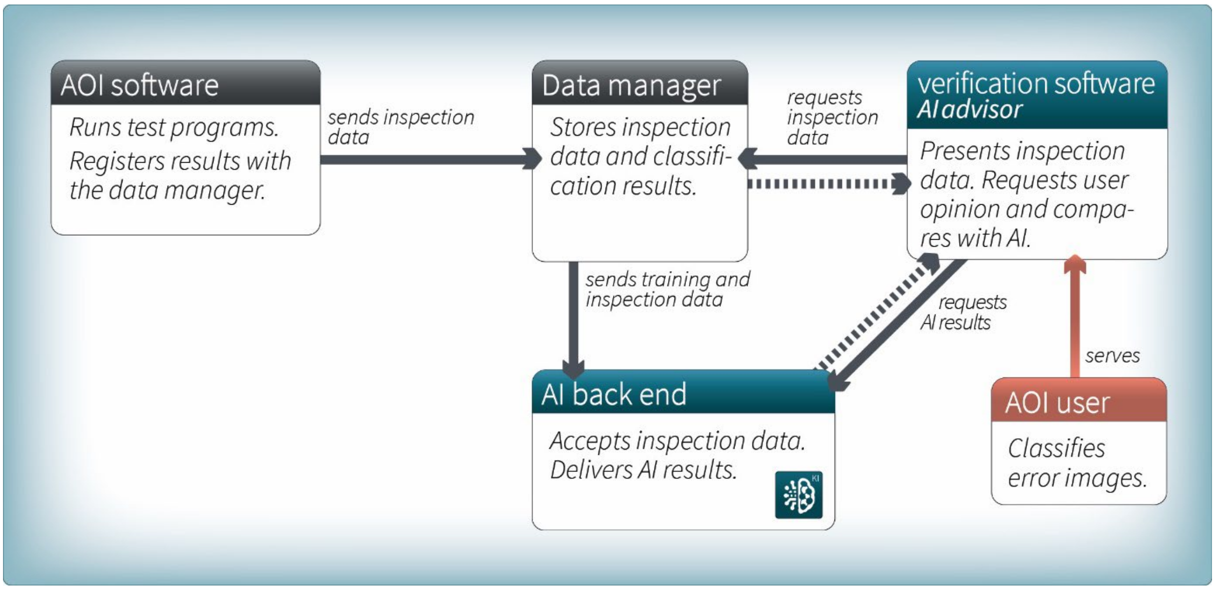

Fig. 4. AI advisor and the AI backend in the context of GOEPEL software applications.

The AI software is designed in such a way that model instances are created on the basis of the error images in a rule-based and thus completely autonomous manner. To ensure that a valid training basis is created in this autonomous process and that it remains valid throughout the life cycle, various mechanisms were integrated. These range from the monitoring or exclusion of image data that are too similar to image data already present in the training set to additional expert interviews (active learning) for individual new image data to be trained.

The developed AI software ecosystem also includes an AI framework for the distributed training and delivery of Deep Learning models and their instances. This tool, which has a web-based, system-independent interface and can thus be accessed conveniently via a web browser, makes it possible to manage the instances with the error images (samples) and their assignment (labels) or, if necessary, to delete samples from the training set.

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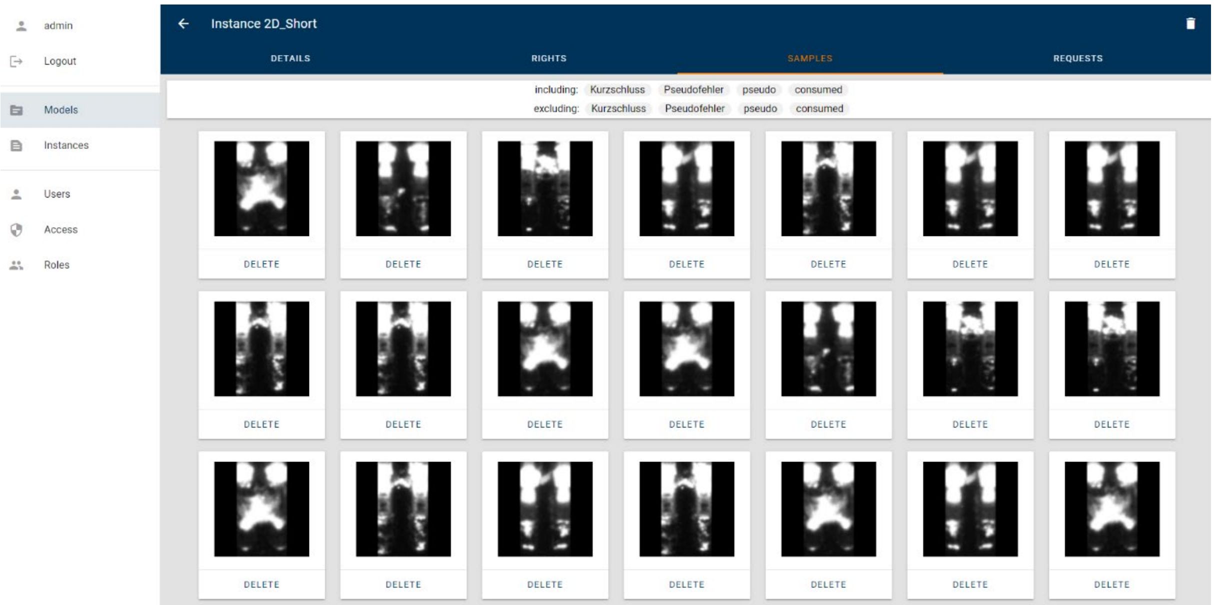

Fig. 5. user interface of the web-based AI framework.

Integration into production infrastructure

AI solutions that are to be integrated into industrial production processes must first and foremost fit seamlessly into the corresponding IT infrastructure. In many cases, production processes are completely sealed off from the outside world for security reasons, as a loss of sensitive data or manipulation of the production systems could cause enormous damage. Cloud solutions can therefore often not be realised and edge-based AI solutions are then the only way out.

For these reasons, the modern architecture of the AI backend of the AI advisor software covers all possible use cases. For electronics manufacturers who have only one production line, all AI software modules can be installed on the same PC as the verification station software.

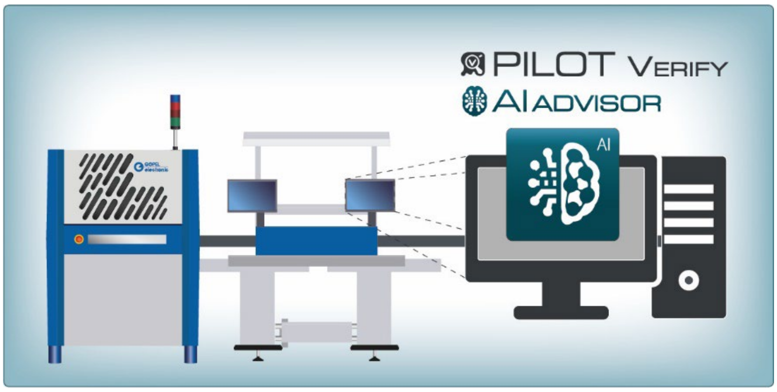

Fig. 6. integration of the AI advisor into a single production line.

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If the production consists of several lines, the AI can run in the company network on a separate AI PC. For users who do not want to install additional computing power, however, a cloud-based solution can also be provided.

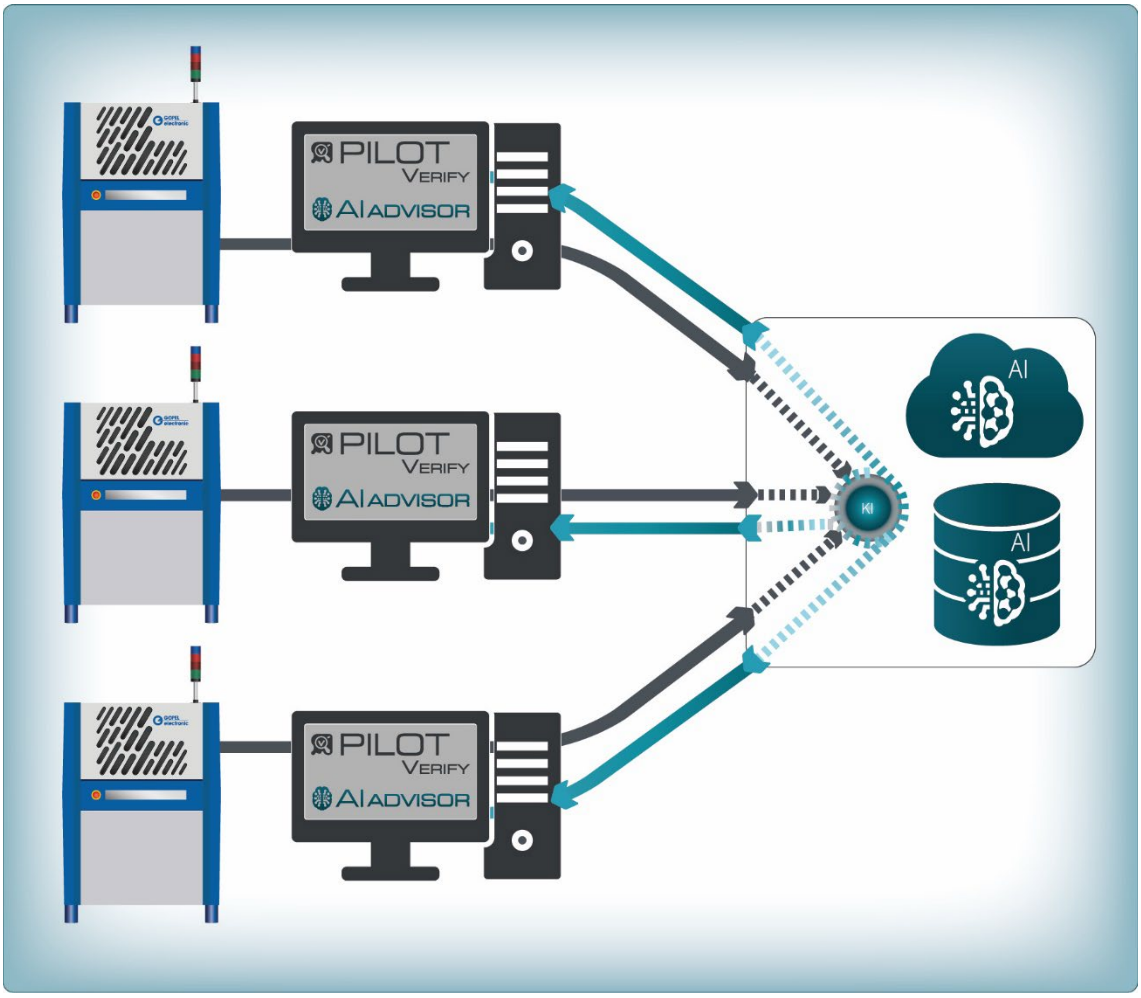

Fig. 7. integration of the AI advisor into several production lines.

Conclusion / Outlook

In the field of automated optical and X-ray inspection, the use of AI contributes in particular to enabling inspection systems to make better inspection decisions or to simplify manual processes. But also the optimisation of production processes based on the collected inspection data is an important topic.

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The newly developed AI advisor software module provides an AI-based assistance function for the PILOT Verify verification software, which ensures that incorrect decisions are prevented during defect verification and that no detected defects are subsequently classified as "pass". Through the interaction of humans and AI, the classification process is optimised and the human is relieved.

In a further development stage, the artificial intelligence then becomes the decision-maker and the occurring defects are classified independently. Verification by the operator is only necessary in exceptional situations when the AI cannot provide a clear result. The automated classification of almost all errors reduces the workload of the operators at the verification stations even more.

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