The road to autonomous inspection. How artificial intelligence is revolutionising AOI and AXI systems.

Whether AI-supported creation of inspection programmes or the automatic AI classification of pseudo defects at the verification station: the first steps on the way to autonomous inspection have already been taken. Currently, assistance systems for AOI and AXI systems are being developed to take more and more work off the operators' hands. But there is still some way to go before optical inspection is fully automated.

Paradigm shift through AI

"Historically, there have been several technological paradigm shifts in the field of AOI and AXI systems," says Andreas Türk, product manager for X-ray systems at GÖPEL electronic. At first, orthogonal looking cameras with manageable illumination variants were used for AOIs. Later, oblique-looking cameras and sophisticated illumination of different wavelengths and directions were added. After that, 3D imaging technology moved into the AOI in order to be able to evaluate solder joints even more reliably. In the field of AXI systems, this development is quite comparable. Starting with the vertical (2D) and oblique (2.5D) radiography of an assembly, mostly still with analogue image intensifiers, 3D X-ray systems for solder joint inspection in several layers gradually developed. With the advent of 64-bit technology and powerful digital X-ray detectors, these were also fast enough for use in the production line for the first time. "Looking back, it was mostly hardware technologies that brought a fundamental change for inspection systems. The next paradigm shift is coming in the area of software," says Türk. Artificial intelligence is the driver for another technology shift here.

Autonomous AOI/AXI system saves costs and personnel

The goal is a fully autonomous AOI/AXI system. But why does this bring advantages? In addition to the acquisition and maintenance costs, it is primarily the costs for the personnel that have an impact on the inspection cost calculation: experts for the creation of the inspection programmes and personnel for the classification of abnormalities found at the verification site. This is where AI comes in to reduce the human effort and save costs. In times of scarce personnel resources, employees can be deployed elsewhere in the company. A clear trend towards customisation is evident not only among German electronics manufacturers - small batch sizes must be produced and inspected quickly and, above all, cost-efficiently. An inspection programme must therefore be able to be created with many assistance functions and a few clicks and must work from the first assembly. Thanks to artificial intelligence, this should be possible in the future completely autonomously, without the intervention of an employee. This will make a significant contribution to reducing inspection costs for very small quantities.

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Where are we today? How will we inspect tomorrow?

Artificial intelligence has already been used in GÖPEL inspection systems for several years. Following the development stages of autonomous driving, stages can be derived for autonomous inspecting. Step by step, the time required for the employees is reduced. Starting with assisted, semi-automated steps up to the final goal - fully automated, autonomous inspection.

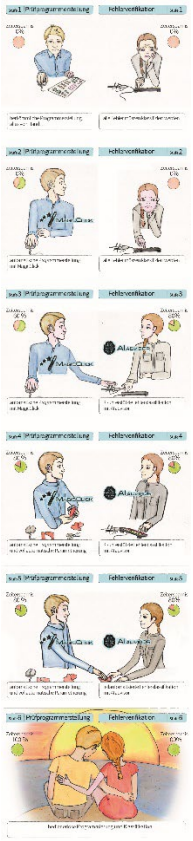

Figure 1: Among other things, AI is used in the creation of inspection programmes and defect classification. The goal: to reduce effort and save costs. Personnel resources can be deployed elsewhere in the company. Image: Tina Dietrich

Already today, the inspection programme creation is automated in the GÖPEL 3D AOI systems. A look back: in the past, everything began with the data import. Afterwards, the article numbers were manually assigned to existing library entries. This was time-consuming because each article number had to be assigned manually. Finally, the test parameters were manually adjusted. But this is history. The now automated programme creation also starts with the data import. After the import, component parameters (name, position, article number, etc.), layout and pad information are available. However, detailed information about the housing and the solder joint (dimensions, height, pin shape) is still missing. For this purpose, the 3D AOI creates an exact image of the respective housing and solder joints using the first produced assembly. In the next step, this information is used

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to determine the respective enclosure shape and to assign all required test functions. The test programme is created and a component library is automatically created based on the article numbers. In the last step, the test programme is executed and the test parameters are automatically adapted to the real process variations. To avoid slippage, tolerance limits are placed tightly around the actual measured values and corrected according to the real fluctuations, taking plausibility criteria into account. This is based on knowledge-based intelligence. In the future, it should be possible to create a test programme without a real image of a first assembly. A completely digital image of the PCB with components and solder joints - the digital twin - will help to create a new test programme without a physically existing assembly.

"There are already AI inspection functions that do not require any setting parameters because they use a pre-trained AI model for classification," explains Mr Türk. As current project examples, he mentions the X-ray inspection of prismatic battery cells for foreign objects or the AXI inspection of sheath thermocouples directly in the production line. As a human being, you often see certain defect features quickly - but the machine needs an expert who has mastered the parameterisation of an inspection function in order to be able to evaluate the feature correctly. This is where AI helps. The AI is trained on the basis of image examples. The result is an AI model that carries out the evaluation without any setting parameters. This is what happened with the evaluation of welded joints on sheath thermocouples (see illustration).

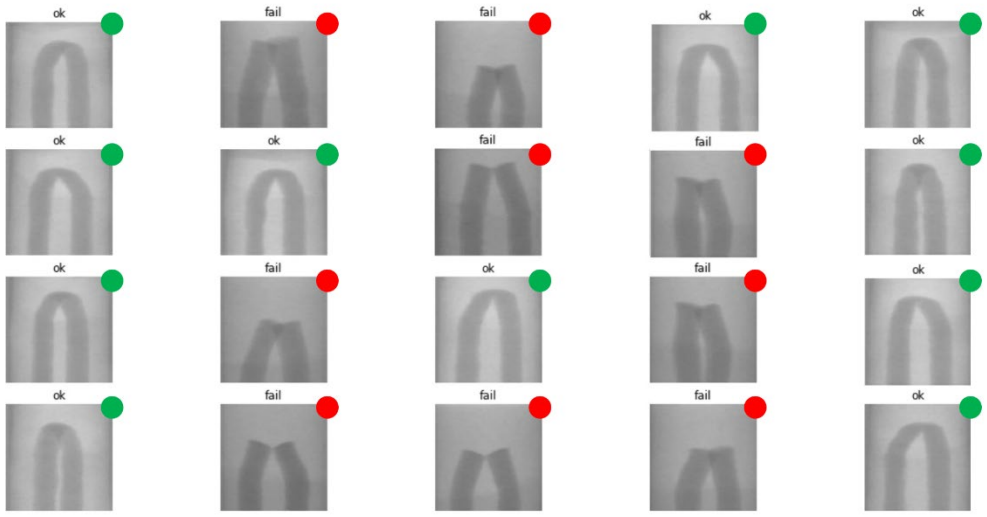

Figure 2: AI evaluation of a welded joint in the X-ray image directly in the production line Image: GÖPEL electronic

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Further AI applications are in the works, for example, in the area of X-ray inspection, AI solutions for void detection, BGA head-in-pillow detection and short-circuit control are being developed. In addition, AI approaches are emerging in the area of predictive maintenance and analysis of results data from all inspection systems in the SMT line. "There is still a long way to go before we have fully automated inspection - but we have already come a long way," says Türk.

Are you sure? AI at the verification station

AI is already saving human resources not only in the creation of inspection programmes. There is also great potential for saving time and costs at verification and repair stations. GÖPEL electronic relies on the AI advisor software module for this purpose.

Figure 3: AI advisor reduces workload for verification station staff; AI also protects against human error Image: Tina Dietrich

Based on pre-trained models, the AI advisor makes its own decision for each anomaly found by the inspection system. The AI decision is based on the verification decisions made by humans in comparable cases in the past. Now there are different possibilities how to deal with the AI decision. On the one hand, anomalies that are classified with high confidence as pseudo errors can be evaluated directly by the AI - without human intervention. This saves time. On the other hand, the AI advisor can warn if a human error would lead to a so-called human slip. If the staff incorrectly classifies a real error as a pseudo error, the user is asked to reconsider his decision. Especially with X-ray images - where interpretation is often more demanding - the AI advisor is a welcome support.

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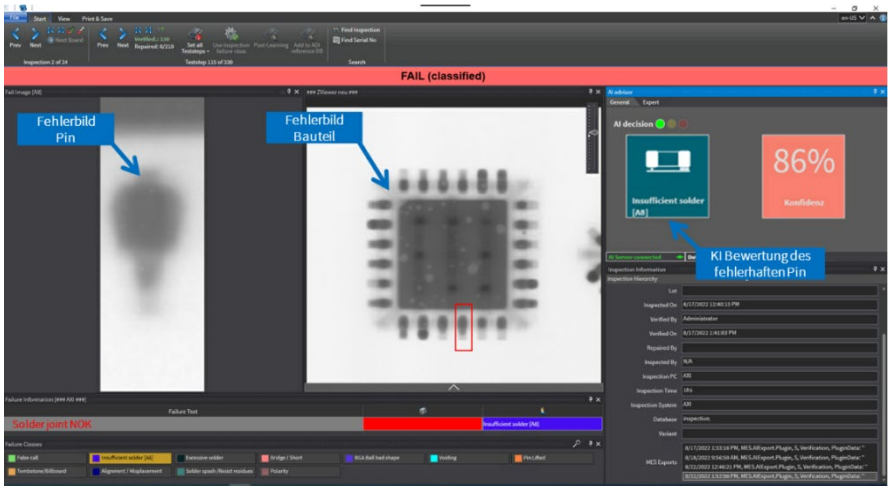

Figure 4: AI evaluation of a QFN pin solder joint in a 3D X-ray image with AI advisor Image: GÖPEL electronic

This AI advisor functionality is constantly being expanded with the aim of a fully autonomous classification of all abnormalities found.

Trust is good - control is better!

"But often there is still a queasy gut feeling about the use of artificial intelligence in the field of inspection systems" notes Türk. Why did the AI decide one way and not another? Does the AI find previously found defects even after it has been trained with new image samples? These are legitimate questions to which the first answers are already available today. The AI must be trustworthy - decisions must be comprehensible. To this end, GÖPEL electronic is working on Comprehensible AI to increase trust and acceptance. "One must not forget: AI is only as good as the human who trained it, and that depends entirely on the selection of data, its completeness and consistently correct labelling/categorisation," says Türk.

Conclusion

There is still some way to go before we reach the autonomous inspection system. The next paradigm shift in AOI and AXI systems, driven by AI, is already in full swing. The goal is clear: AI should save personnel resources and reduce inspection costs. Already today, assistance functions are available for inspection programme creation and defect verification. These are constantly being expanded up to the autonomously operating inspection system.

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