Xplain Data
Discover Causality

SIEMENS ERLANGEN – CASE STUDY

PCB MANUFACTURING: HOW SIEMENS MOTION CONTROL BREAKS THE 5 SIGMA WALL WITH CAUSAL AI

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ERROR RATE BELOW 5-SIGMA

The introduction of Causal AI has opened a new chapter in PCB production. As part of a Proof-of-Concept project, the Siemens Erlangen plant succeeded in reducing the error rate in PCB production to below the demanding 5-sigma wall. This demonstrates how holistic data analysis and AI-supported root cause analysis can optimize production standards.

As a pioneer of digital transformation, Siemens Motion Control in Erlangen, Germany, is relying on Causal AI to revolutionize production processes. By seamlessly linking and analyzing all data across the entire value chain, they achieved a new level of transparency and efficiency. The result: optimal product quality, cost savings, accelerated processes and a decisive competitive advantage.

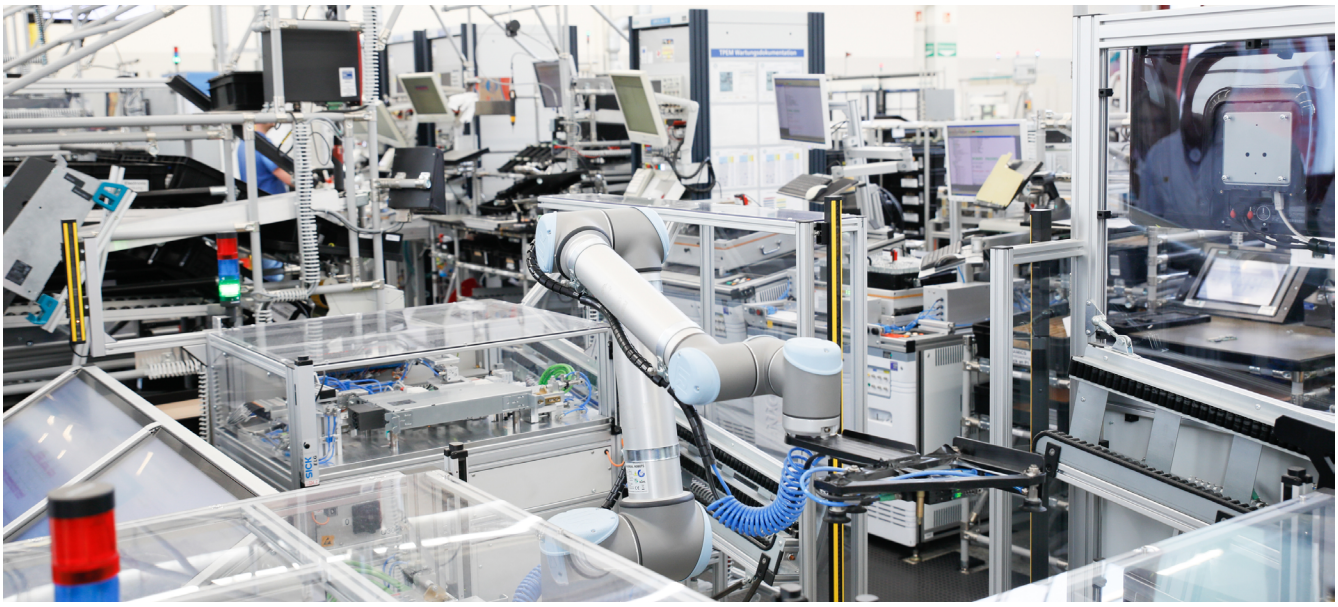


Fig. 1: Electronics production, Siemens Erlangen

The Siemens plant in Erlangen, a digital flagship plant, specializes in the production of high-precision industrial drives for automation and motion control. At the heart of these drives are specially designed circuit boards. Production is a complex - and therefore error-prone – process following these steps:

1. *Print the PCB with solder paste using a product-specific stencil*
2. *Check the quantity and position of the solder paste for each component contact*
3. *Place the electrical components on the board (50 - 1,500 components per board)*
4. *Solder the circuit board using the reflow process based on product-specific temperature profiles*
5. *Identify faulty component placements, solder bridges and open solder joints in the final automatic optical inspection (AOI)*

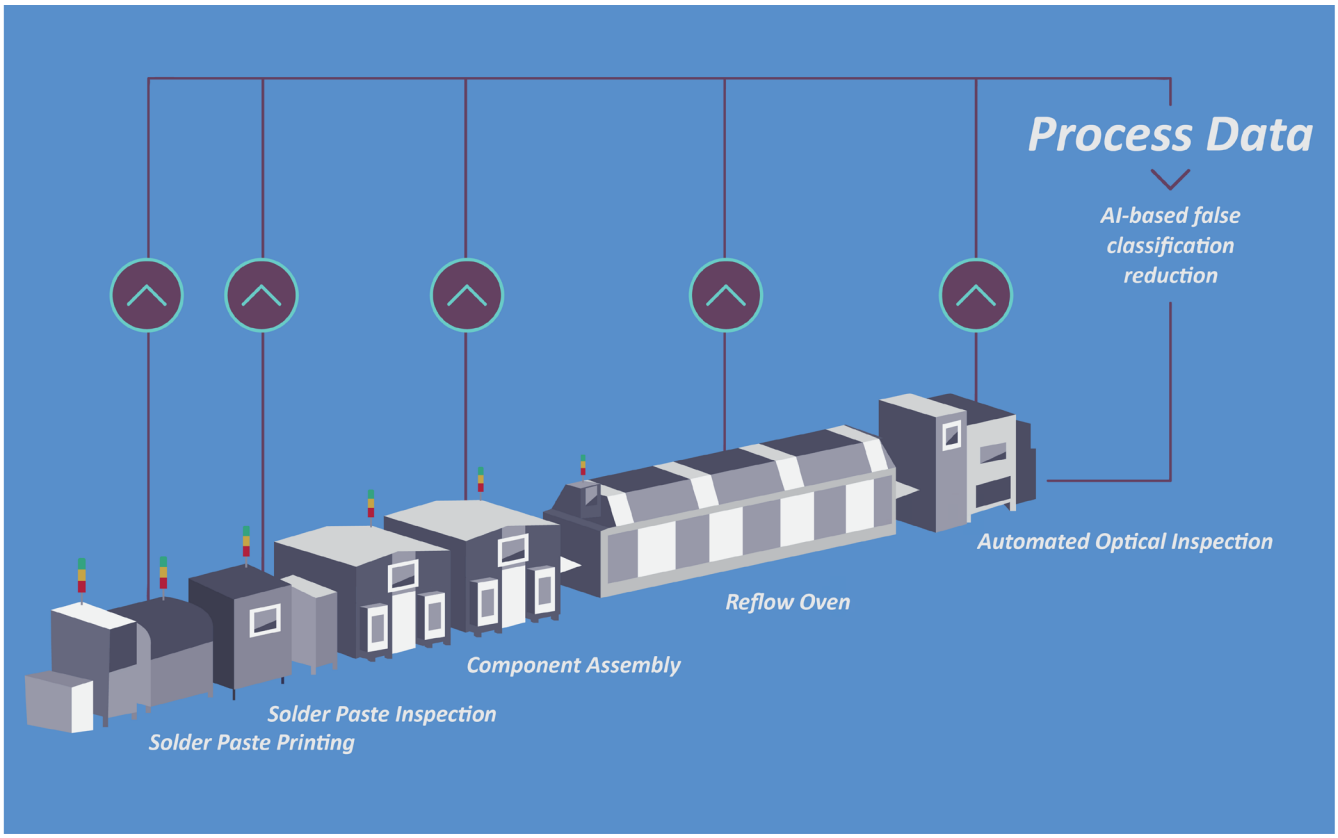


Fig. 2: Typical PCB production line with automatic optical inspection (AOI)

Although the PCB production process was highly stable, the results were not meeting the required quality targets: to achieve a defect rate of less than 3.4 per million possibilities and reach the required Six Sigma level. This required a thorough overhaul of quality control and extensive data analysis.

THE DATA PUZZLE: A CHALLENGE FOR PRODUCTION

PCB production collects 500 million data points every day, generating a wealth of information that has often been viewed in isolation. Until now, data-driven problem analysis along a production line requires extensive manual data engineering to integrate all data sources and create a complete baseline. As a result, a comprehensive understanding of the entire production process to detect errors and optimize manufacturing has typically been missed.

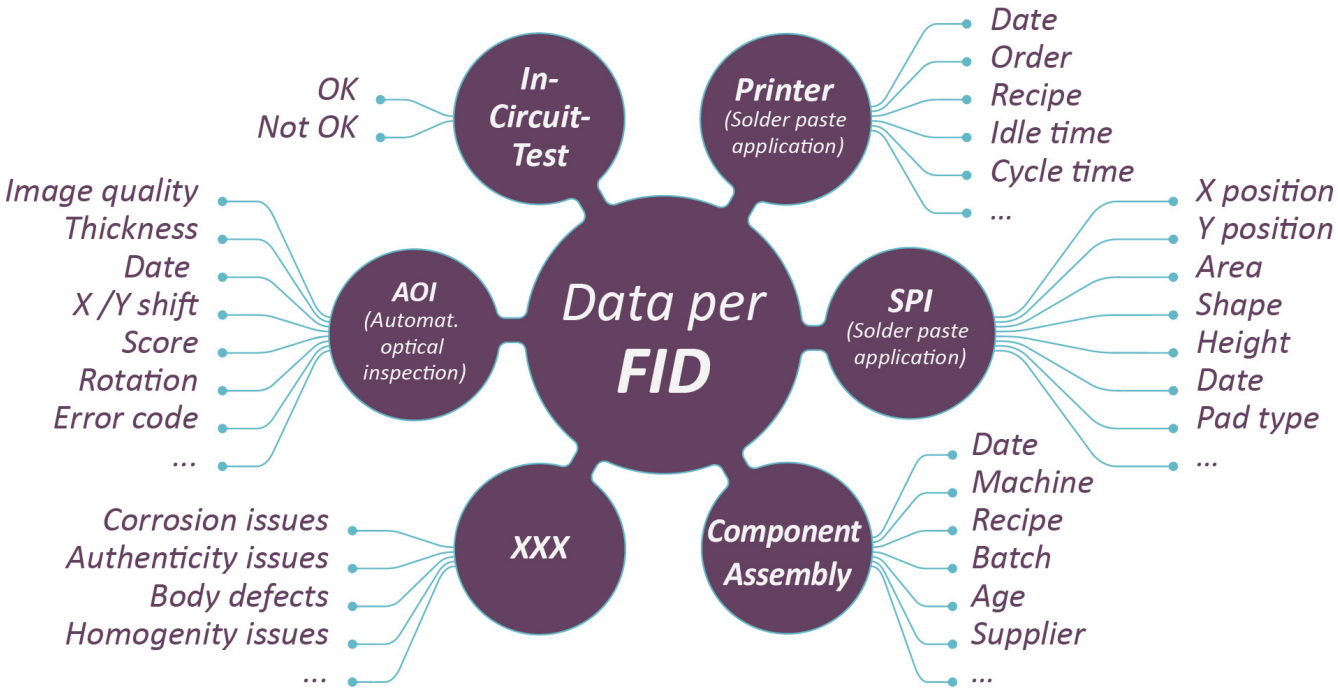


Fig. 3: Production steps with resulting data per 'fiducial' (reference point)

What is Causal AI?

Causal AI is an innovative approach to AI that focuses on discovering cause-and-effect relationships in complex data. Unlike predictive methods that only predict what will happen, Causal AI explains why certain events occur. This enables manufacturers to identify patterns in data and gain deeper insights into their processes. This allows for targeted production optimization, reduced downtime, improved product quality and increased efficiency.

Causal AI is well-suited for production lines where full traceability of individual parts is available.

Causal AI is rapidly gaining momentum for Industry 4.0, as the latest Rockwell Smart Manufacturing Report shows.

In a 2024 survey of 1,500 decision makers from 17 major manufacturing countries, Causal AI ranked first in terms of planned investments over the next 12 months. It is rated as one of the best technology solutions to support the workforce and offers an exceptional return on investment (ROI).

CAUSAL INSTEAD OF PREDICTIVE – SIEMENS RETHINKS

Faced with a complex data landscape in PCB production, Siemens made a paradigm shift: to implement the Causal AI technology from Xplain Data. The goal was to comprehensively analyze data across all production steps in order to significantly reduce the error rate and thereby achieve Six Sigma quality levels.

Xplain Data, founded in 2015, specializes in the causal analysis of complex data. Originally applied in the healthcare sector analyzing complex patient data to uncover causal factors of healthcare problems, Xplain Data has successfully started to apply its methodology to industrial production.

Unlike traditional predictive models, which only predict future events (What will happen?), Causal AI makes it possible to identify the underlying causes of production problems (Why is this happening?). In healthcare the object analyzed is the patient, in manufacturing it is the produced part.

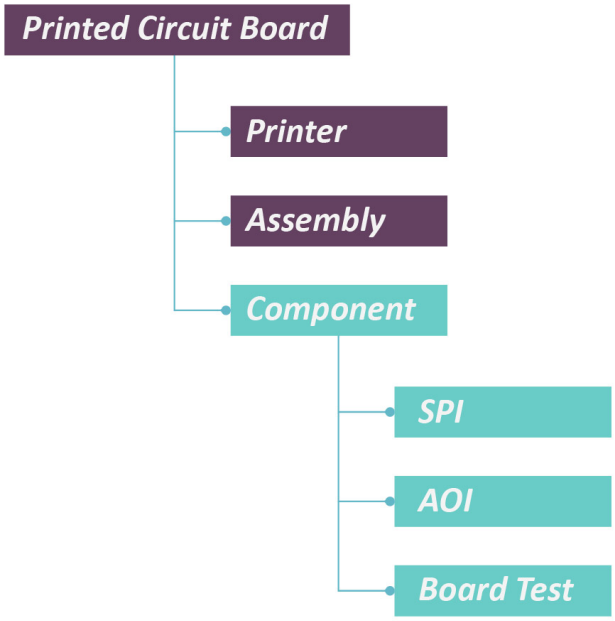
This causal information related to production issues now forms the basis for targeted intervention and optimized PCB manufacturing. Once the causes of desired or undesired events (or effects) are identified, errors can be rectified and positive results reinforced.

EVERY ASPECT IN FOCUS: OBJECTANALYTICS

The patented ObjectAnalytics technology provides a comprehensive 360-degree view of each PCB - the central object analyzed. The method uses an object-centric approach, combining all relevant data into a central object model with its main and sub-objects. In PCB manufacturing, the 'PCB' is defined as the main object, while each 'component on the PCB' represents a sub-object. For each of the 500 components, readings are collected from every stage of the production process.

By integrating all data into a central object model, correlations and dependencies are analyzed accurately. For example, design parameters, solder paste print results and inspection results can be analyzed together to identify problems that only occur when combining these factors.

With just a few clicks of the mouse, the technician can create a powerful graphical analysis of the root causes to all problems that occur.



***SPI** (Solder Paste Inspection)*
***AOI** (Automated Optical Inspection)*
***Board Test:** Listing of all confirmed 'Not OK' results*

Fig. 4: The object tree for PCB production. The object at the centre of the analysis is the printed circuit board (PCB) and hence the main object, with the explicit identification of the 'component' entity, as this was found in many analyses to be more important than the whole PCB.

CAUSAL AI: BREAKTHROUGH IN PCB QUALITY

Causal AI technology was introduced in three steps: object-centric consolidation of production data, identification of causal relationships and continuous optimization. This systematic approach drastically reduced the production error rate. A significant success in PCB production was breaking the 5-sigma barrier (less than 3.4 defects per million possibilities). Automated analysis now makes it possible to identify potential causes of defects at an early stage of production and take targeted action.

The AOI station could identify previously undetectable causes to design-related failures using Xplain Data's Causal AI processes. As a result, Siemens was able to significantly improve the quality of its PCB production and break the '5-sigma wall'.

Fig. 5: A localized visualization of the parameters based on the position of the component on the board was found to be very helpful. A corresponding 'heat map' display was integrated into the functionality of the Causal AI solution.

NEXT STEPS AND CONCLUSION

The next step is to implement this solution in daily operations to sustainably increase the contribution to value creation.

To maintain this achieved quality, it is planned to implement the autonomous Xplain Data Causal DiscoveryBot. The DiscoveryBot will continuously monitor the production process (process control) and provide early warning of potential problems and causes that could endanger the production line to the QM team. This will lay the foundation for AI-supported collaborative problem solving in the areas of quality and process engineering.

Siemens also plans to extend the integration of causal methods to the assembly of the entire device.

Cost-benefit analysis was another important aspect of the project. Within a year, the investment in the Causal AI technology from Xplain Data had paid for itself.

Erik Schwulera concludes: "Causal AI is an important part of our digital transformation. In addition to significantly reducing the error rate and improving production quality, it opens completely new possibilities for supporting and easing the workload of our quality and process experts!"

Erik Schwulera, *Lead*
IoT@Manufacturing and
Six Sigma Director,
Siemens Digital Industries

"Causal AI is a game changer for us in electronics production. We can now fully automate quality work, especially root cause analysis," concludes Erik Schwulera.

"By implementing the holistic ObjectAnalytics data model, which is based on the entire object tree, we are, for the first time, able to simultaneously analyze the effects of Quality in Process and Quality in Design in a holistic way. For us, this represents a breakthrough in how we can improve production."

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