White Paper
August 2024

IT@Intel: Using Natural Language Processing to Streamline Manufacturing Failure Mode and Effects Analysis

Intel Manufacturing Automation is using AI to analyze factory tool logs and user comments—reducing FMEA effort from weeks to seconds

Authors
Dr. Steve Chadwick
Senior Principal Engineer
Foundry Manufacturing Supply Chain

Table of Contents

Executive Summary

Intel Manufacturing Automation has developed an innovative methodology for performing failure mode and effects analysis (FMEA) in manufacturing by using artificial intelligence (AI) techniques to analyze users' emotional tone—positive, negative, or neutral—about the manufacturing equipment.

Traditionally, FMEA involves time-consuming manual extraction and analysis of large text data from tool logs and other sources, leading to weeks of engineering effort per analysis. This approach must be repeated across large fleets of tools by the engineers who support these tools.

Our new approach uses natural language processing (NLP) and sentiment analysis (SA) to reduce the labor required for FMEA from weeks to seconds.

Integration with our in-house factory data analytics platform, Data on the Spot (DOTS), further democratizes FMEA results by enabling users to easily access this data and use it to identify root causes from the original sources. The system is now deployed across all Intel semiconductor factories, with a focus on front-end manufacturing.

This transformative approach promises to dramatically streamline the FMEA process, freeing up engineers' time to focus on developing innovative solutions to further enhance Intel's manufacturing tools and processes.

Contributors

Joe Sartini, Global Domain Lead, Industry 4.0

Acknowledgments

Kalpana A. Algotar, Intel Data Scientist
Hasanul Karim, Intel Data Scientist
Aswathy Rejendra Kurup, Intel Data Scientist
Nicholas Kahlor, Intel Developer

Acronyms

DOTS	Data on the Spot
FMEA	failure mode and effects analysis
NLP	natural language processing
SA	sentiment analysis

Business Challenge

Failure mode and effects analysis (FMEA) is a critical process in manufacturing that is used to identify potential failures, assess their impact, and prioritize preventive actions. The FMEA process involves breaking down the system into its individual components; analyzing each component for potential failure modes; determining the effects of these failures; and assigning a risk priority number based on severity, occurrence, and detectability.

Traditional FMEA involves manually extracting large amounts of text data from tool logs, statistical process control (SPC) systems, and other sources. Data is extracted using scripts, and then weeks of engineering time are spent analyzing the results.

The complexity of Intel's manufacturing environments further compounded the challenge. Each fab has thousands of tools in production, and each may run multiple operations. This meant that engineers had to perform thousands of potential FMEAs, with each analysis taking several people weeks of part-time effort.

We realized that the time and effort invested in FMEA could be spent more effectively on developing innovative solutions to enhance Intel's manufacturing processes, but an alternative approach was required to address this critical work.

Solution

Intel Manufacturing Automation proposed a game-changing solution: Replace manual FMEA processes by performing sentiment analysis (SA) on tool logs and other data sources using natural language processing (NLP) techniques.

NLP focuses on analyzing and understanding human language in a computational way. It involves processing large amounts of text data to extract meaningful insights and patterns.

SA is the process of analyzing and understanding the emotional tone expressed in a piece of text, such as a review, comment, or social media post. The goal is to determine whether the text conveys a positive, negative, or neutral sentiment. The practice of SA arose from the analysis of Twitter posts by researchers for US movies and fashion lines, who mined tweets that mentioned their products to predict whether a movie would be a blockbuster or a new dress design a hit.[1]

Using SA for engineering tools was a big leap—we were not aware of anyone in semiconductor manufacturing who had done it before—and management was skeptical of our methodology. However, we believed that using SA for FMEA was a good fit. Factory engineers and technicians who work with tools on a daily basis make notes in the tool logs, and those notes express emotions—even on dry topics like manufacturing tools.

Our SA analysis extracts keywords from comments, notes, SPC charts, and quality systems data to find words with negative connotations about a tool, such as "abort," "alarm," "fail," among others. We've customized the analysis for domain-specific language, such as words and phrases that are specific to the semiconductor fab environment (e.g., "defect" and "excursion"). We also implemented custom replacement keywords ("ABORT" vs. "ABT" vs. "ABRT") to accommodate various abbreviations and spelling errors commonly found in tool logs and other data sources.

The system analyzes sentence structure and filters out brackets for HTML and other special characters used in programming languages, allowing for a wide variety of inputs. While Intel's manufacturing logs are predominantly in English, the libraries can be extended to handle multilingual input.

Integration with DOTS

Intel Manufacturing Automation built our FMEA capability as a stand-alone analysis capability of our existing in-house factory data analytics platform called Data on the Spot (DOTS).

DOTS combines data from thousands of manufacturing tools using dozens of databases across all the factories in our global network. It pulls data from offline databases so as not to affect production capabilities and aggregates it into a big data lake.

Implementation of the FMEA system involved utilizing open-source Python libraries for NLP and SA, with in-house software development to tailor the models for semiconductor-specific language and requirements.

We executed the initial iteration of the system, then added features like replacement keywords and addressed edge cases. Development began in 2023 and rollout took six months.

By incorporating FMEA capability into DOTS, our system helps to democratize the results of FMEA by enabling users to use a familiar platform to access data that they might not otherwise have known existed.

[1] For example, see this paper: Giri, C., Thomassey, S., Zeng, X. (2018), "Analysis of consumer emotions about fashion brands: An exploratory study."

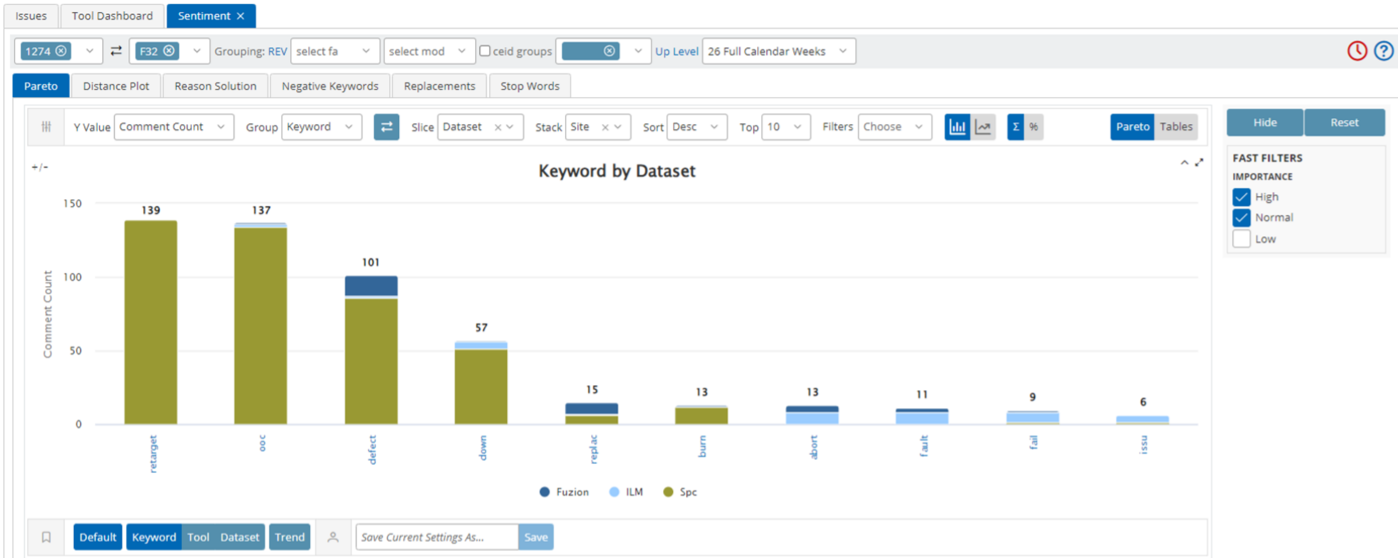

Figure 1. FMEA data as shown in Intel's internal Data on the Spot (DOTS) platform.

Engineers can use the output from our SA analysis to drill down on words and phrases to see the original comment, which helps them discover exactly what the problem was and identify the root cause.

Figure 1 shows multiple data sources working in conjunction to bubble up themes, which can be interactively explored using a Pareto chart. The chart indicates which areas offer the most opportunities to drive improvement.

When a user clicks a Pareto bar, they see the text of the original comment. Multiple items stacked on the Pareto chart provide opportunities to investigate whether an event appears in more than one data source.

Solution Architecture

The Intel® architecture-based components of our new FMEA system enable us to deploy new features rapidly. The FMEA system is powered by Intel® Xeon® processors, which provide the computational power and performance needed for real-time analysis of large datasets (see Figure 2).

The system uses high-speed SSDs and advanced memory configurations to ensure rapid data access and processing. Fast Intel® Optane™ persistent memory is employed to enhance caching capabilities and accelerate data retrieval.

Results

We tested our new FMEA methodology for the etch process as a proof of concept. When we compared the traditional approach to our SA-based system, the software discovered everything the engineers found with their manual system approach—plus even more that they missed. Our system performed FMEA on six months' worth of data in under one minute, saving weeks of engineering time.

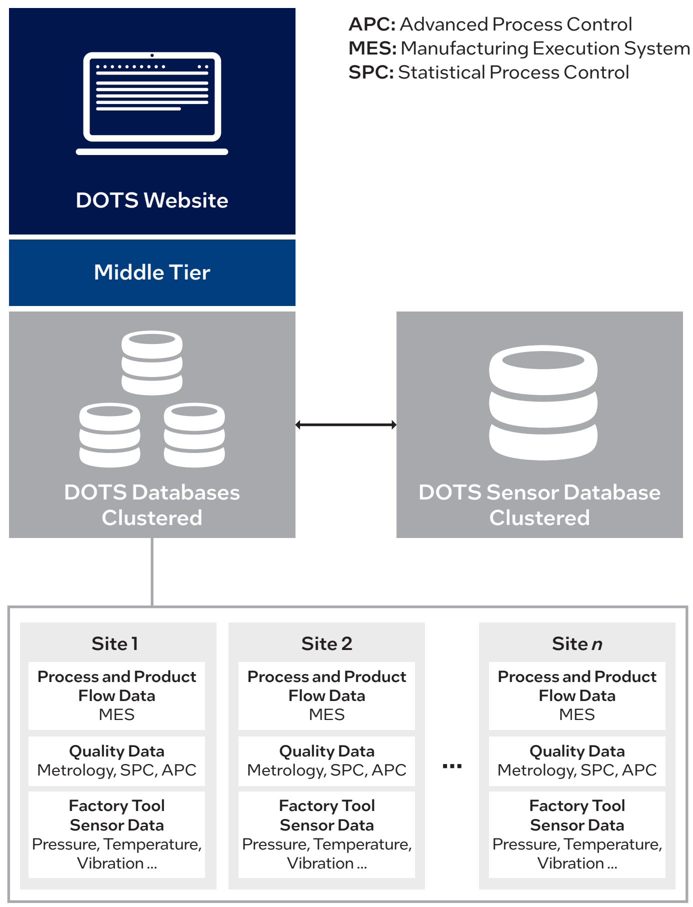

Figure 2. Data on the Spot (DOTS) data lake infrastructure.

Hardware and Accelerator Specs

Sensor Database Cluster (billions of rows of data)

- **Processor:** Intel® Xeon® Gold 6242R processor (3.1 GHz/20 cores/205 W) FIO W
- **Database Drives:** Several large-capacity SSDs
- **Memory:** 1.5 TB DDR4 RAM

Accelerator

- **Processor:** Intel Xeon Gold 6244 processor (3.6 GHz/8 cores/150 W)
- **Database Drives:** 3.2 TB NVMe Gen3 High-Performance Mixed-Use SFF SCN U.2 DC P4610 SSD
- **Memory:**
  - 128 GB Intel® Optane™ persistent memory 100 Series (Memory Mode)
  - 32 GB DDR4 memory (used as cache)

Next Steps

The system has been incorporated into existing business processes at Intel to benefit the entire organization, with a primary focus on front-end manufacturing.

We also have extended the system to allow engineers to extract concepts that are considered neutral in order to investigate mechanisms of interest. For example, when working with chemicals, the word "nozzle" may be of interest. Extending the system enables engineers to extract data based on various criteria to enhance analysis in new ways.

Conclusion

Intel IT's groundbreaking use of NLP to identify negative events by analyzing user comments in factory tool logs dramatically reduces the time it takes to perform FMEA.

As a result, engineers no longer need to laboriously gather and analyze data. Instead, their time can be spent on developing other innovative solutions to improve Intel's manufacturing processes.

Related Content

If you liked this paper, you may also be interested in these related stories:

- Accelerated Analytics Drives Breakthroughs in Factory Equipment Availability
- Minimizing Manufacturing Data Management Costs
- Reliability Engineering Helps Intel Cut IT Manufacturing Systems Downtime in Half

For more information on Intel IT best practices, visit intel.com/IT.

IT@Intel

We connect IT professionals with their IT peers inside Intel. Our IT department solves some of today's most demanding and complex technology issues, and we want to share these lessons directly with our fellow IT professionals in an open peer-to-peer forum.

Our goal is simple: improve efficiency throughout the organization and enhance the business value of IT investments.

Follow us and join the conversation on **X** or **LinkedIn**. Visit us today at **intel.com/IT** if you would like to learn more.

intel®

0824/WWES/KC/PD