Center of Excellence in ADVANCED & SUSTAINABLE MANUFACTURING

Machine Learning & Artificial Intelligence in Advanced Manufacturing

In a new era of industrial innovation, intelligence is key. Knowing how product design can affect manufacturability or how production processes can affect finished quality helps manufacturers make critical decisions in support of fundamental business goals. This kind of information is invaluable, made possible largely by design analysis tools, advanced sensing systems, and other technologies that leverage machine learning to provide critical data analytics. Today's technologies are able to predict design success, product performance, and equipment failures, providing key information that helps manufacturers continuously improve. But despite these benefits, the potential for machine learning—and, more broadly, artificial intelligence—to revolutionize the manufacturing industry is yet to be fully realized. These technologies make complex systems work better by supporting engineering decisions with real-world data, but as we move towards Industry 4.0, their true potential lies in automating solution implementation and control. To get there, we must go beyond data analysis alone; we must find ways to let machines solve problems on their own.

What are Machine Learning & Artificial Intelligence?

Machine learning is an evolving field of study that enables computer-controlled programs to collect process data, recognize patterns in it, and make inferences from those patterns. Machine learning is itself a subfield of artificial intelligence (AI), where computers may be enabled to adjust functions or performance parameters without being explicitly reprogrammed to do so. When a spam email filter begins to recognize common types of email content as illegitimate, for example, that is machine learning. When the same filter acts on that knowledge to automatically divert spam mail from the inbox, without anyone telling it to, that is artificial intelligence.

These capabilities are accomplished by changing the way computer-driven processes are controlled. Conventional controls govern through a set of directions—called *program instructions*—that define the conditions for, and execution of, a given task. Program instructions are usually static and strict, meaning any changes meant to improve performance must be made to them directly, fundamentally altering the way a task is defined and done. In contrast, machine learning uses algorithms—a kind of mathematical Q&A—to recognize patterns in data, models expected performance based on these patterns, and predict the outcome of different scenarios based on these models. These inferences allow artificial intelligence to then compare solutions and identify the best option.

How is it Used in Advanced Manufacturing?

While machine learning has been employed in areas from medical diagnosis to language processing (as in your smart -phone's personal assistant), application in manufacturing is often met with technical and business challenges. As Jane Zavalishina highlights in *Advanced Manufacturing*, many would-be adopters remain skeptical of potential costs, learning curves, and operational disruptions, or struggle with uncertainty over where artificial intelligence can even fit into an existing manufacturing system. Luckily, artificial intelligence technologies come in many forms and can address several aspects of a manufacturing business, from production efficiency to quality assurance.

The potential impact of machine learning is perhaps highest, as a 2016 *Forbes* article suggests, in asset health and manufacturing processes monitoring. In this context, embedded machine sensors collect data on factors like vibration, temperature, and electrical activity and report to a software platform for analysis. Computer algorithms recognize patterns in these data and are able to predict things like the rate of wear, time to component failure, or

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the optimal time to perform maintenance to minimize asset damage, opportunity costs, and process disruption. Another example, well-known in manufacturing, are machine vision systems that inspect finished products after manufacturing. Here, intelligent algorithms enable computers to turn digital information captured in an inspection image into an assessable report on product characteristics, which is then used to make a judgement on quality. In either case, computer-controlled processes use machine learning to infer useful information that might otherwise have gone unnoticed—such as a failing process element or tool wear affecting product quality—allowing engineers to intervene proactively.

Why Isn't It Everywhere?

Although machine learning is at the core of many existing data analytics systems, few are presently able to allow the machines themselves to make decisions. For the most part, current intelligence technologies determine changes in performance by highlighting when measured values for key indicators differ from nominal, or expected values. While this can suggest emerging or impending problems, it relies on operators and engineers to determine the cause for such deviations and subsequently develop appropriate solutions. Existing systems are thus limited in their ability to identify cause-and-effect relationships, largely because technologies to collect the necessary type and volume of data are likewise limited in development, and the algorithms needed to reliably determine such relationships are exceedingly complex. The benefits are still clear; current technologies can improve operational efficiency, reduce costs in rework, and facilitate proactive maintenance. Substantial opportunity remains, however, to empower manufacturing systems with human-like abilities of critical thinking and problem solving, and therein unleash a new level of intelligent manufacturing.

What Does the Future Hold?

Machines that determine cause-and-effect relationships, model potential solutions, and execute ideal courses of action through artificial intelligence are possible, and the potential benefits will revolutionize the manufacturing industry. Existing tools in product design, for example, can model performance characteristics based on structure and material, but any actual changes to design must be made by hand and tested again. In the future, tools like parametric design will become a staple of manufacturing. Building on conventional tools, parametric design uses defined parameters for performance, weight, dimensions, or others factors to automatically create digital models, simulate manufacturability and performance, and use insights from these simulations to iterate until it finds an optimal solution. Not only does this speed up the design process, it also explores, identifies, and evaluates many possible design changes before producing a final result—virtually eliminating the need to go back and change a design at a later time. Likewise, in process optimization, intelligence systems like GE's Digital Twin are today able to predict failures and suggest potential solutions, but the next generation of machine learning will go beyond reporting for operator decision and instead allow algorithms themselves to find and execute ideal courses of action. If patterns in use data from a wind turbine, for example, reveal that mechanical wear increases with ambient temperature, intelligent systems could identify a thermal threshold for operation in order to maximize the turbine's life, and even adjust it as wear continues. Similarly, if an inspection system for CNC-machined components finds an increase in defects at high tool speeds, advanced machine learning could predict the potential effects of different tool speeds on both process efficiency and product quality. Using historical data to model future results, an intelligent system may then automatically adjust tool speed to optimize both, improving throughput while minimizing costs in rework, retooling, or manual system adjustment. In any context, this ability to self-adjust begets continuous improvement in performance, durability, and reliability, benefitting manufacturers by improving operational efficiency while reducing frequency, intensity, and costs of maintenance.

With artificial intelligence and machine learning, advanced manufacturing can become more autonomous, efficient, and profitable. And while the importance of big data in manufacturing is emerging, we remain at a critical point between quality and availability. In order to capture the potential of advanced manufacturing and create new advantages, then, we must collaborate to bring these technologies into the next generation.

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