MANUFACTURING POLICY INITIATIVE AT O'NEILL
INSIGHT INTO MANUFACTURING POLICY

AI and Manufacturing

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Artificial intelligence (AI) is changing the world. "More profound than electricity or fire," says Google CEO Sundar Pichai. Indeed, AI is being used in transportation (easing traffic congestion), medicine (predicting congestive heart failure), banking (making loan decisions), the arts (writing rap songs), law enforcement (setting bail and predicting recidivism), national security (processing drone footage), science (predicting aftershocks from earthquakes), and agriculture (monitoring grapes at vineyards).

And it is being used in manufacturing. In fact, AI is ideally suited for situations where data are abundant and relatively homogenous, and the environment is well-controlled, such as the factory floor. The wide range of current and potential applications is also creating regulatory challenges for firms.

What Is AI?

AI was originally defined as a machine that could think like humans. Over several decades, the definition has changed. Today, AI is about creating systems that can perform tasks that seem to require human-level intelligence. A subset of AI is *machine learning*—finding patterns in training data and then using those patterns to make predictions about future data. The exponential rise in applications of machine learning in recent years is due to the increased availability of large data sets, improved algorithms, and more powerful computer hardware. *Deep learning*, a subfield of machine learning, structures algorithms in layers to create a "neural network" that can learn and make intelligent decisions on its own.

Machine learning is often embedded into other modern technologies. For example, machine learning is used in *augmented reality* (AR)—an interactive experience where the objects that reside in the real-world are "augmented" by computer-generated perceptual information, which can be constructive (in addition to the natural environment) or destructive (masking of the natural environment). Whereas augmented reality alters perception of a real-world environment, *virtual reality* replaces the real-world environment with a simulated one.

In recent years, machine learning has been used to give new abilities (improved vision, grasping of items, and greater motion control) to traditional industrial robots and also to collaborative robots, or *"cobots"*—robots intended to physically interact with humans in a shared workspace.

Yet another important term is *generative design*, which is the use of AI software coupled with cloud computing to create design options by simply defining the design problem and providing input parameters. Generative design relies on machine learning.

Applications by Category

From a comprehensive search of the academic literature and trade press, we sought to identify and categorize AI applications in manufacturing. Our focus was on machine learning because it represents the fastest growing segment of AI, according to the annual *AI Index*. We chose to narrow our search to applications that have already been adopted by specific companies, and we excluded applications common to businesses in general such as financial management, fraud detection, customer service, ad monitoring, etc.

Table 1 summarizes our findings. Manufacturers are using AI to serve a wide variety of purposes: workforce training, product design, production process improvement, quality control, predictive maintenance, supply-chain optimization, distribution, and AI-embedded products.

The effectiveness of AI and its adoption by manufacturers relies heavily upon not only the machine-learning and deep-learning algorithms but also on the inherent limitations of complementary technologies (e.g., the quality of the suite of sensors that provides the data for AI algorithms).

Many manufacturers are using AI for workforce training. For example, Jaguar Land Rover is using an AR-integrated training app to train new technicians without removing and reinstalling the vehicle dashboard. AR is also being used to provide safety training, especially in hazardous situations. AGCO, an agricultural equipment manufacturer, has used AR to reduce its training time from 5090 days to 30-45 days.

Manufacturers are using advanced robotics that utilize machine learning to improve the efficiency of the production process. For example, Ford uses cobots to help humans fit shock absorbers onto cars at one of its assembly plants. Nelipak Healthcare Packaging uses AI-enabled cobots to load trays and put heat-sealed lids on them. AR is also being used to improve production. Boeing is using AR to help its production workers with wiring of the new 787-8 freighter. At AGCO, assembly line workers use AR glasses to increase efficiency in tractor assembly.

AI is being used to improve quality control primarily through faster and more accurate inspection of products. For example, an aircraft engine manufacturer is using AI to inspect turbofan blades with greater precision and speed. Hot sauce maker Tabasco uses AI to ensure the correct placement of labels on 1,000 bottles per minute. At Porsche, engineers use an app on a tablet that employs AR, which utilizes machine learning, to obtain design information on auto components such as surface finish, and to test power windows and lights.

AI is being used to optimize supply chains in numerous ways, including planning, warehouse management, logistics and shipping, natural language processing (for sifting through data in foreign languages), and managing supplier relationships. Lennox, an HVAC manufacturer, uses machine learning to model highly variable seasonal demand patterns and better manage its North American supply chain. IBM used cognitive technologies, including AI, to reform its global supply chain management. Infinera, a California telecom manufacturer, used AI to make better predictions about delivery dates by considering many more variables than it would otherwise have been able to process.

example, Siemens is installing smart sensors on older motors and transmissions; the resulting data can be analyzed to detect irregularities. Mueller Industries, which makes a variety of metal and plastic products, has tested an AI-enabled system to monitor the sounds of a machine to determine when maintenance may be needed, and is now exploring how the system can be used to prescribe a solution.

Table 1. AI Applications by Category

Category	*Description*	*Early Adopters*
Workforce training	AR is being used to train employees.	Jaguar Land Rover Agco
Product design	Generative design is being used to develop new products.	Adidas Airbus
Production process improvement	AI is being used to enhance the capabilities of robots on production lines. AR is being used to assist production workers.	Ford Nelipak Healthcare Packaging
Quality control	AI is being used to identify defects faster and with greater accuracy.	Porsche Tabasco
Predictive maintenance	AI is being used to monitor machines to determine when maintenance is required.	Siemens Mueller Industries
Supply chain optimization	AI being used to manage supply chains more efficiently.	Lennox IBM
Distribution	AI is being used to increase the autonomy of vehicles used in distribution within and outside of a factory setting.	Whirlpool Omnitracs
AI-embedded products	AI is being embedded into new products that have greater customer utility.	Toyota IDx Technologies DroneDeploy

In predictive maintenance, AI is being used to monitor equipment and predict when a machine may break down, thereby reducing downtime. This is done through sensors that notice subtle changes in vibration or energy use. For

Manufacturers are using generative design software to create new product options, which can then be optimized with human assistance. It is already being used to create lightweight critical parts in satellite, aerospace, and defense applications. Adidas used generative design to create its Futurecraft 4D shoe, and Vitamix used generative design to create rinse nozzles for its commercial

blenders. Airbus used generative design to redesign an interior partition for its aircrafts to decrease the weight of the part, which reduces fuel usage and greenhouse gas emissions.

Semi-autonomous and fully autonomous vehicles can be found within manufacturing operations. The list includes free-range automated guided vehicles (AGVs), inventory robots, mobile robots, autonomous forklifts and cranes, and low-payload drones. A 2018 survey indicated that 10 percent of manufacturers are using semi-autonomous or autonomous vehicles within their operations.

United States freight transportation is currently not using fully autonomous vehicles, but driver-assisted technologies are common, including active braking assistance, adaptive cruising, and cameras to check driver's eyes for sleep deprivation. Omnitracs, a fleet management software company, is using machine learning to create dashboard cams that can detect certain activities and behaviors of the vehicles driver, such as driver fatigue. Having this capability improves truck safety, increases efficiency, and lowers operating costs. According to a 2018 survey, 5 percent of U.S. manufacturers are now using semi-autonomous trucks.

AI can also be embedded within a manufactured product to better meet the needs of consumers. Nearly all of the examples described previously rely on AI-embedded products (e.g., Toyota manufacturers AGVs). Two other examples are medical devices and unmanned aerial vehicles or drones. One medical device manufacturer has created a screening test for diabetic retinopathy, a disease that can cause blindness. The test involves machine learning software that can analyze the image of an eye taken in a doctor's office. Another company has developed software that can analyze computer tomography results to identify patients at risk of a stroke. DroneDeploy, a commercial drone maker, has created MapEngine, a cloud-based image processing software for drones. It can be used to create 3-D maps more quickly than humans processing drone footage.

Regulatory Challenges

As AI applications become more common, three types of regulatory challenges are emerging: outdated regulations that preclude innovation, uncertain regulatory requirements that impede investment, and new regulations that impose a compliance burden.

An example of outdated regulations is federal motor vehicle design standards to ensure automobile safety. Such standards, written under the presumption of a human driver, preclude self-driving vehicles that are currently under development. The keeper of these standards, the National Highway Traffic and Safety Administration, recognizes that it must alter its regulations to allow for innovation and is undertaking several specific rule changes to address the issue.

Some regulatory programs create uncertainty for manufacturers pondering investment in AI. Examples include programs at the FDA and EPA. FDA rules require drug manufacturers to follow current Good Manufacturing Practices (cGMP). Are AI-enabled factories allowed under cGMP? Manufacturers wishing to invest in such applications would like to know the answer. Under its New Source Review (NSR) program, EPA requires the installation of modern pollution control equipment when a factory is built or modified in a manner that could increase pollution. Could the installation of AI to control the operation of a factory trigger NSR? Investment decisions depend on the answer.

Finally, new regulations to address AI will impose a compliance burden. Examples include medical devices based on machine learning and aerospace parts created by generative design. These products require government review or approval before they can be brought to market. Federal regulators have either developed, or are in the process of developing, new guidance or requirements applicable to such AI-enabled products.

Manufacturers who employ AI should engage with federal regulators to ensure that evolving requirements provide public protections without unnecessarily impeding innovation.

Peer Reviewers: Brian K. Paul, Professor of Manufacturing Engineering, Oregon State University (OSU); Venkatesh Iyer, Vice President, IBM; Gloria J. Wiens, Associate Professor, Department of Mechanical and Aerospace Engineering, University of Florida; and Xiaowei Yue, Assistant Professor, Grado Department of Industrial and Systems Engineering, Virginia Polytechnic Institute and State University.

For Further Reading:

Eric Brynjolfsson and Andrew McAfee, “What’s Driving the Machine Learning Explosion?” *Harvard Business Review*, July 18, 2017.

David Crandall, “Artificial Intelligence and Manufacturing” in *Smart Factories: Issues of Information Governance*, Manufacturing Policy Initiative, Paul H. O’Neill School of Public and Environmental Affairs, Indiana University, March 2017.

McKinsey & Company, 2017. “Smartening Up with Artificial Intelligence: What’s In It for Germany and Its Industrial Sector?” April.

Yoav Shoham, Raymond Perrault, Erik Brynjolfsson, Jack Clark, James Manyika, Juan Carlos Niebles, Terah Lyons, John Etchemendy, Barbara Grosz and Zoe Bauer, "The AI Index 2018 Annual Report”, AI Index Steering Committee, Human-Centered AI Initiative, Stanford University, Stanford, CA, December 2018.