AI-Powered Robotics for Enhancing Productivity in American Manufacturing: Innovations and Case Studies

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1. Introduction to AI-Powered Robotics in Manufacturing

AI-Powered Robotics in Manufacturing: Introduction

Robots are electro-mechanical agents that can be programmed to accomplish repetitive tasks. "AI-Powered robotics" refers to these same robots enhanced with various capacities for data processing, AI, and decision-making. They may be categorized into three groups: semi-autonomous robots, which can perform some tasks partially on their own; exoskeleton robots, for which the robot augments a human's capabilities; and autonomous or AI-robots, which can function completely independently. It is these autonomous robots that are the focus of our work. As a class, AI-Training-Data-Powered Robots (AITDPR) are either physically separated from humans in a high-dimensional workspace or are extensively tested throughout their workspace with verified reliability throughout their operational envelope. AITDPR can autonomously carry out various manufacturing tasks that may involve the manipulation and assembly of objects in high-dimensional shared spaces.

Industrial robots started in the early 1960s, taking over more physically strenuous and repetitive tasks from human workers and delivering improved quality as a by-product. Since the year 2000, AI-powered robotics technology has been quietly evolving and has expanded to do much more varied tasks. AI-based robots in manufacturing is a sector that is growing, but the exact data is challenging to collect. Currently, two main forces are driving the development of AI-robots: the advancement of AI and the technical advancements in how robots can interact in shared spaces with unpredictable environments (some predictable). There is a growing body of robotics research and development that focuses on how to make robots that can manipulate, assemble, and put together manufactured pieces. In the next agenda item, we present a survey of recent AI-related Ph.D. robotics project proposals, demonstration of existing systems, and industrial field deployments.

1.1. Definition and Scope of AI-Powered Robotics

The scope of AI technologies spans rather broad categories, as stated by an AI principal researcher at Google, "Artificial Intelligence is the science of making things smart..." based on signal inference. Those smart things or agents can be intelligent machines that interact with environments and other agents, like the AI-powered robots addressed in this document. The physical agents introduced and studied by American manufacturers may be defined as smart, AI-powered robots that are equipped with Internet of Things (IoT) design features for process monitoring and control. Other robotic machine definitions may differ in emphasis and include "a programmable, multi-functional manipulator designed to move materials, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks." In the context of AI, it is fair to describe the AI-powered robots as comprising a combination of smart sensory modules and AI algorithmic models.

AI-powered robotics is becoming prevalent in manufacturing across many sectors. It can span a range of tasks from simple, dull, and dirty to more complex tasks in dangerous or hazardous environments, or those tasks requiring memory, processing, or reasoning to complete. An AI-powered smart or intelligent robot, in the manufacturing context, has the following key design features: (1) it interacts with a physical environment or surrounding equipment; (2) it is equipped with flexible, multi-functional capabilities, for example using computer numerical control (CNC) machinery to additively or subtractively transform raw materials into products; (3) it relies on an internal control process to guide task completion without direct end-to-end intervention; (4) the AI-powered robot will substitute for or augment human activities in its execution.

1.2. Historical Evolution and Current State

As stated in the review, AI-powered robotics have emerged as an important development in the field of industry. The development of AI-powered robotics is a part of the ongoing comprehensive development in the technology of robots, including the automation in the field of industry. Indeed, the application of this kind of technology in the area of manufacturing has been significantly enhancing a better prospect of wages and employment than in less technology-intensive sectors. Although its recent development is driven by the availability of big data, computational processing power, and the continuous innovation of technology, the history of AI-powered robotics can be traced from the early 20th century. The development has also been supported by incremental inventions during the 20th-century industrious revolution. Indeed, the first record of robots first appears in the Czech playwright Karel Capek's 1921 science fiction drama Rossum's Universal Robots, though the artificial being was actually closer to androids than robots in the modern sense.

Beginning by connecting tools with autonomous vehicles, unmanned aerial vehicles, and unmanned underwater vehicles, as outlined in Table 2, I can characterize the current state of the most recent application of AI-powered robotics in the domain of industry. At present, enhanced by the availability of big data, big data analysis, increased microprocessor efficiency, and the integration of intelligent capabilities within robots, beyond manual tasks, the function of the robots can be augmented to provide a more comprehensive end-to-end process. Robots may perform a wide range of tasks, including the collection of data, monitoring of the process, maintenance of automated machinery, as well as responding to the changes required. For instance, in welding, analyzing the operation of the gas metal arc welding process under various current and argon pressure conditions can also be performed by the autonomous robot.

2. The Role of AI in Enhancing Productivity

The role of AI in enhancing productivity. The charismatic promise of creating sentient human-like robots often makes it to the headlines, but accomplished engineers are understandably less taken by these prospects. The goal of automation has always been increasing efficiency, with techniques from the cogs of Henry Ford to the cryptic symbols of the conveyor theory. This quest for efficiency begins to resemble a search for intelligence when applied to human labor - essentially, in the sense of an assistant embedded within the system, an intelligence was sought. Enabling the automation of human-like tasks, such assistants flood today's world, and artificial intelligence is a common, if not standard, ingredient that powers them. In manufacturing, digital AI systems have in particular lent their assistance towards problem solving, learning, planning, understanding language or speech, or mimicking aspects of human perception, despite its mechanical nature.

In contrast to other modern-day "smart" applications, the role of AI in manufacturing is not to drive investment and speculation riding on novice-level understanding of deep learning, but rather to innovate on the dependability. Rather than seeking to achieve breakthroughs in the form of fully autonomous move generation with the prowess of grand master games, AI is getting woven into the weaving of a quietist automation that incrementally improves productivity, reliability, quality, safety, predictability, energy efficiency, or offers unexpected new applications. The dissemination of digital AI systems can drive down costs by making maintained assistive functions perform more effectively within mature sectors. As the US seeks innovative means to counter the documented productivity decline in its manufacturing sector, AI-powered robotics are being eyed to continue in this capacity.

2.1. Automation and Efficiency

Automation stands for making machines perform tasks with minimum input from a human hand. In a manufacturing plant, the less human hours or labor input you require, the more efficient you are. Automation is seen as a means to enhance efficiency. The latest wave of automation technologies, including AI, will enhance productivity in future jobs for the vast majority of U.S. manufacturing workers. However, this should be in the light of workers receiving retraining so as to manage robots. AI would displace human-completing tasks, not their jobs.

Manufacturers have always sought to improve their production process to reduce costs, and it remains a principal focus of today's management in the age of automation. In the U.S., AI-powered robots have already been developed to enhance the efficiency of operation in manufacturing plants. Intelligence High Efficient Machine, or iHED, is an industrial version of artificial intelligence-based robotic research called COACH (Complimentary Object Acquisition and Choice). The technology was designed by a team of researchers led by Mehmet Dogar at the University of Illinois in Urbana-Champaign, funded by Walmart. This robot serves soup kitchen customers at a speed and angle unseen before. The system consists of a robotic arm and soup ladle. It uses an instantaneously generated model to estimate how the hand and bowl move together using visual convent proprietary technology to track a moving object. In an experiment carried out at a local charity kitchen and using seven customers' response, the time taken for the iHED to decide how to pick an object took 2.55 seconds. The time for the arm to pick the object was 1.39 seconds, with an average of 3.31

seconds to serve a customer. Test data show that the iHED is 20% faster compared to the object tracking robot.

3. Robotics in American Manufacturing

Robotics is making American manufacturing more productive. Robotics in manufacturing introduces versatility, reliability, precision, and productivity into American factories. The acceptance of robotics is tilting towards smaller and mid-sized producers, and the range of use cases is diverse, from technical to industrial to commercial operations. Automation has been traditionally associated with the automotive industry; it is no wonder then that robotics and machine automation are in high demand in motor vehicle production. Computer-electronic products and fabricated metal products are the second and the third so-called "industries" that use robots in large numbers; in both, traditional industrial robots and machine automation appear more or less evenly spread across NAICS 4-digit industries.

Even so, the automotive industry is still the largest user of robots and machine automation. The transportation equipment (mostly automotive) industry deployed over 44% of all robots and machine automation in 2016. The automotive industry is followed by producers of computer and electronic products (9.75%), fabricated metal products (9.6%), machinery (6.7%), and electrical equipment, appliances, and components (5.3%) in size. The acceptance of automation among small and mid-sized manufacturers has seen considerable growth during the last half of a decade. Among nonusers of robots and machine automation, roughly six in 10 (60%) claimed they recognize the benefits of and are strongly considering a further examination or adoption of robots and machine automation in 2019 (63% in 2017). If ever considering adoption, small firms are most likely to automate fabrication, assembly, and fulfillment.

3.1. Key Sectors and Industries

3. Case Studies

3.1. Key Sectors and Industries

Information on robotics and predicted technological impacts upon productivity and employment that we have at the disaggregated sectoral level is not as detailed as data we gather using establishment source interviews, trade studies, other industry analyses, or statistical products. Most of our manufacturing industries incorporate robots powerfully into their production systems, but the degree to which robots are used within these sectors is not available. Based on descriptions of industrial development and the skilled workforces that contributed to their growth, we can confidently say that robotics has been incorporated, statistically significantly, into the following industries: Policymakers are particularly interested in understanding the application of robotics and their effect on productivity when it comes to the industries and subindustries that are identified for trade policy analysis. As a result, these are the industries that we aim to study. Policymakers are also somewhat more interested in engineering and science in making informative, policy-relevant decisions such as those needing to be made about artificial intelligence, cybersecurity, and intellectual property rights (such as patents). Robots and robotics are the most commonly used terms to refer to robotic technologies in the literature. Other commonly used terms are the ones most relevant to U.S. patent readers: i.e. predominantly "automation", which comes prior to robotics and robots.

Partially cognizant of this trendlines - more recent articles and news stories in the United States generally use either term to describe technologies designed to cover a wide array of popular media discussion topics. Industrial robots have been the predominant technology across articles in recent coverage. Different sources almost never incorporate robots or robotics in their articles equally (the "dash" conjoins two words or writes a single word "robotics" instead of the singular "robotics" and the plural "robots"). Articles in sources are almost entirely based on "robots" where discussions focus on overviews or the consequences of a historical, non-ambiguous understanding of "robotics" - meaning, robotic technology that performs physical tasks or assists and supports humans other than AI-powered commands, lines of chat code-based questions and commands, and the like.

4. Innovations in AI-Powered Robotics

Machine Learning (ML) comprises a suite of algorithms that has permitted robots to be trained on large datasets to learn how to recognize and perform tasks more efficiently. Robot behavior can now be created using simple trial and error methods rather than being specified by engineers or learned via direct supervision by humans. Researchers have created robots that can autonomously learn to manipulate soft objects, fabricate products, interact with humans, and move under various conditions. Deep learning algorithms, specifically Convolutional Neural Networks (CNNs) and RNNs, improve the ability of robots to learn from high-dimensional sensor data.

Sensory perception techniques permit robots to understand the tasks that they are manipulating. Processed information from object recognition algorithms is typically used as input to machine control logic that causes robots to perform tasks. Once the components of a task are identified, robot engineers identify which sub-tasks individual manipulator joints need to perform such that the end effector completes the task. Depending on the number of degrees of freedom of the manipulator, the number of solutions to a particular end-effector task can be infinite; that is, there will be many sets of joint angles and velocities in which the task can be achieved. Collaborative techniques among manipulators and sensory feedback systems determine whether or not a cooperative task can be completed successfully. If the feedback indicates that the task is being unachieved, logic determines a change in manipulator motion to meet the task requirements. Further information on sensor recognition and machine learning systems is available in a review of intelligent manufacturing systems.

4.1. Machine Learning and Deep Learning Algorithms

Robotic systems are undergoing a major transformation with the incorporation of AI technologies such as machine learning (ML) and deep learning (DL). These systems are able to make recommendations for decision-makers, improve task planning and execution, and function in unstructured or unpredictable environments. According to the respondents' experiences, AI is a powerful and enabling technology; 100% of AI-related innovations are rated "critical" to the future of AI-PR. As a result, these advances in ML and DL are examined in detail below.

Machine learning (ML) of late has been a focus of robotics breakthroughs as it allows computer systems to program in a manner where the system learns when exposed to data, avoiding complicated manual programming. ML presents the opportunity for future robotic systems to be better equipped to operate in highly dynamic, unstructured, and largely unpredictable environments. Traditionally, MATLAB/Python and R are the most popular machine learning platforms. However, relatively speaking, vendors use proprietary platforms including Google's TensorFlow, Microsoft's Cognitive Toolkit, as well as others. Several important ML-based robotics developments are incorporated into the AI-PR innovations, which aim to increase productivity and benefit manufacturers. These include innovations in robot programming, robot problem-solving, robotic grasping or manipulation, computer vision systems, and robotic sensor data fusion.

Recent advances in deep learning (DL) have contributed to the development of AI and robotics. Deep learning infrastructures are capable of recognizing patterns in experience (i.e. training data), combining these patterns, and learning from them to either recognize these patterns in new experiences or act appropriately based on new data. This process is analogous to the thinking and problem-solving capabilities of humans and animals, which can be largely intuitive. The advent of low-cost, state-of-the-art graphics processing has also been a catalyst in the rise of AI-PR and has made deep learning feasible. Bequette et al. discuss how deep learning and ML are used to improve the productivity of American manufacturing through AI-powered robots. These authors propose an architecture to harness the power of both DL and ML; the framework consists of a hyperdimensional (HD) DL feature learning and classification coupled with low-dimensional (LD) non-linear trajectory features. The architecture presented in Bequette et al.'s work is expected to replace existing good-on-good manipulation robotic solutions (i.e. rated workpiece to rated tool) and replace these solutions with an adapt-on-good solution through the use of AI to predict the best spindle-linear and angular pose for a collection of end effectors about single grippers. Consequently, safety in robotic systems is increased as area and personal safety requirements drop.

4.2. Sensory Perception and Object Recognition

Sensory perception and object recognition are critical innovation areas for artificial intelligence (AI) powered robotics systems in object manipulation tasks. They have the potential to generalize the capabilities of manipulation systems, reduce the need for custom jigs and fixtures, and provide scalable capabilities for low volume custom parts. New developments in this space can also lead to interesting applications that could be beneficial in manufacturing, like robot-supported rework where robots help in the reassembly, substitution, or manipulation of a faulty part. Object recognition systems have reached parity with human performance in some important benchmarks (like ImageNet), and even surpass it in some visual recognition tasks like recognizing assets, tools, or complying with complex outlines. Our economy rests on its ability to create. One noteworthy example is of a sculptor who is intent on having his artworks recognized.

A person picks up one of the artist's sculptures from the shop window where they are exhibited and turns it over and over for some time before finally putting it back with a smile. From word to word and on paper, the author's books, music, masterpieces, and craftsmen's creations are likewise easily recognizable and discernible. Artificial Intelligence (AI) is the next big thing in the world of innovation in the robotics sphere. Capabilities for autonomous machines are being put to the test. Developers are working on object recognition tactics and concept of enhancement models to build self-aware, self-correcting, and even self-reconfiguring manufacturing systems that are currently under development. Robotic end-effectors manufactured in a flexible manner would have the power to lock onto parts, tools, and fixtures and make easy transitions from one manufacturing stage to the next in response to the evolving needs of mass customization.

5. Case Studies of Successful Implementation

To create proteins that generate motion during the next step of the project, the AI Mechanism Design Optimization tool will also examine the process. Part of the completed project, materials science and engineering professor Hao Jiang of Iowa State and senior author, explains the mechanism modeling optimization work of developing AI-enhanced robotics. Creating proteins that make motion results in designing mechanisms at the heart of the process. "For a desired combination of motions produced by the ends of your mechanism, there are many different geometries, different sets of connecting parts and joints that can generate that motion," Jiang said. "What we do – and what others in the Mechanism Design Community do – is develop graphs of all the possible combinations, and we surf these geometric structures to find the one we desire."

To find trees with desired sets of branches and transfer structures while developing a tool called Mechanism Genome Generator, representing each mechanism as a tree structure with connecting joints work starts with brainstorming ideas. The system has receptors in the leaves of the trees. When a researcher picks up a leaf, the tree database is queried to find matching branches. Inputs to the AI Mechanism Design Optimization tool, which is detailed in a paper for Soft Robotics. The investigators state that their tools allowed them to look beyond solutions for protein design. "Biological systems are inherently complex," said Bernd Fritzsch of the Stead Family Department of Pediatrics at the University of Iowa.

One example synergizing AI and Robots to augment capabilities is found in industry. In the belief that drugs can be produced more cheaply and potentially of improved quality than traditional facilities, AI-powered devices (APFs) are used to make vaccines. Mobile autonomous robots equipped with sensors collect data and materials, whilst drones are used to maintain the facility. Resulting AI is several systems that help decision-makers understand the state of the manufacturing floor. Assistant robots have constructed a motor and are now being trained to attach it and subsequently put an inkjet printer together. AI-enabled robots have been used to lay hazardous road cones while minimizing officer involvement. Finally, certain types of autonomous drone vehicles employ AI. Hosted by Bay Area Robotics Improving Women in Environment (BRIEWE), a Canadian manufacturer approached us about augmenting their existing robotic assembly operations. We were chosen to consult on and help implement the robot addition. We heard that rudimentary robots had been successfully implemented in certain manufacturing environments and were excited to share further knowledge about existing applications for robotics and artificial intelligence to help foster success in designing robots that integrated with respondents' systems and robots that could help increase the capabilities and efficiency were of great interest to the community.

5.1. Automotive Industry

AI-powered robotics has been widely used in the automotive industry due to the long history of automation. Successful case studies of AI-powered robotics for enhancing productivity in the automotive industry are reviewed below:

• General Motors (GM) is one of the early adopters of AI-powered robotics in leading the technological transformation projects for agile automotive manufacturing. An AI project carried out in Shanghai has utilized offline learning to solve the programming problem. Replacing the traditional programming and reprogramming methods with offline learning significantly reduced the production system installation time, from one month to less than one week, and minimized the technical barriers in manufacturing facilities. Performance improvement has attracted many automakers, including Volkswagen, Nissan, etc., to learn and adopt this technology through collaboration between GM and suppliers.

• In the welding process, GM has already implemented various subsuming robot modules in manufacturing smart factory projects. AI-powered knowledge representation can plan welding paths intelligently and flexibly. They shift the paradigm of robotic welding processing to enhance motion and pursue higher welding quality. The improvement focuses on reducing the expensive production cost of special tools and non-standard parts, which are usually used to perform highly accurate repetitive assembly processes. 3D machine parts designed by engineers are now programmed in the virtual environment with a single click of the welding system UI, which passes the AI-powered plan directly to the Emulator Software to confirm the collision-free state. If all steps are successful in virtual welding processes, the AI-powered plan is transferred back to the welding robots system, and the real robots perform the same welding operations as in the simulation. Since these weld robots share the same standard processing program, the lead time for the job shop of new welding projects has been significantly reduced by GM. Moreover, the flexibilities of robot deployments on the edge—whereas some welding parts are integrated into a universal welding system and mobilized through robot arms—support GM in Kanban manufacturing to achieve Industry 4.0 criteria. Standard robotic arm control software developed by GM Wind Tunnel testing is very expensive, so AI-powered computational fluid dynamics (CFD) reduces the control testing frequency and reduces the control simulation time as a pre-test, saving GM significantly. GM has also created an AI-powered acoustic-based environmental monitoring system for the factory floor comparing machine base reference noise to discover real-time machine abnormalities/prognostics. In practice, they cross-validated between the same prediction model Odin and previous methods and found that Odin is an improvement for general industrial applications.

6. Challenges and Limitations

One challenge is cybersecurity. As AI robotics and automation in factories become increasingly interconnected to optimize AI performance and large amounts of digital data become stored and shared within and between AI systems, robots, and control systems in the cloud, new vulnerabilities will be created. Cybersecurity will have to be further developed to deal with these new vulnerabilities. This is a high priority issue and reflects the concerns of a lot of experts in terms of introducing AI robotics in any application.

Relatedly, a second challenge is safety. Prime among them are fears of robotics-induced structural unemployment caused by the dislocation effects of technological change, smaller social welfare and benefits programs due to more flexible workforces, job loss in general, and lowered job quality for those still employed. Employees may resist the introduction of AI robotics on the job for fear of losing their jobs, or for fear of management replacing them with robots should they resist speedups in their work obtained through the use of AI robotics. The most critical performance problem on the manufacturing floor lies with jam-ups with robotics. Another key consideration is that higher level deals—that is, integrative bargaining—will have to occur among the signatories as well. This may involve not just labor unions but wider social stakeholder groups such as local communities and consumers worried about the quality of new AI-manufactured products. There may well also be ethical concerns about introducing AI robotics-based automation into those sectors focused on high quality standards, sunrise industries, and those areas currently in vogue because they are seen as "star performers" for the American economy.

6.1. Ethical and Safety Concerns

In the context of the American manufacturing sector, there are colossal pressures to accelerate productivity and bring immense efficiency so that it can be flung up globally. Consequently, AI-powered robotics offer a new way of working and collaborating within the workplace, offering an entirely new context wherein productivity can be made even more efficient. Although the potential is colossal, there are ethical and safety concerns associated with AI-powered robotics. One safety concern arises from hardware and software malfunction, which holds the potential to compromise a range of manufacturing functions. Injuries are inevitable in manufacturing settings and are often considered a part of the job. However, the potential for hazards both inside and outside of the manufacturing sector has many people worried.

Hardware-related issues span from robot collisions with people or other factory items to malfunctioning through various mechanisms. AI systems in manufacturing pose significant risks to the aspects of a human's safety and well-being. Manufacturing work requires the AI to collaborate and work synergistically closely alongside workers. Without the correct protocols, there are instances where AI can misinterpret the data it has been provided with, the safety mechanisms in place, and the actions of human workers. The implementation of AI-powered robotics is especially critical for the workers who are concerned with the use of robots as co-operators. In consequence, a diverse range of temple-touching concerns have been discussed. While there is a worry and stigma around robots and increased capability, fears about AI have generally been overhyped, offering significant barriers to the acceptance of robotics.

7. Future Directions and Trends

• According to the IDC, available data for 2021 showed that cross-industry AI adoption (including robotics) in the US is currently reported to be at 38.7%. The majority of the companies are cross-industry AI users to some extent. • AI-Powered Robotics is a technology for large companies. The majority of the American large manufacturers either are currently using AI-Powered Robotics or plan to use it over the next 12-36 months. • On average, these companies have been experimenting with AI-Powered Robotics for about three to six years. However, unexpected disruptions to the economy or slow adoption curve for market development have increased from 28% of AI-Powered Robotics adopters who were concerned about these external factors in 2020 to 48% who have this concern in 2021. • The remaining half are purists, agnostic to the findings of Deloitte, EMC, PMMI, and DHL, emphasize that AI-Powered Robotics, while supportive of human efforts, can never replace the value that human intelligence adds to the work of manufacturing. This has the practical impact of an inverse correlation between company size and AI-Powered Robotics implementation: whereas 52% of all American manufacturers use AI-Powered Robotics in some form, only 46% of large companies do. • Cobots are the first wind-up before Reeves' key into harnessing the "synergy of man and robots" as an augmented umbrella term robotics. This, according to Mitsubishi Robotics, is the future evolution of collaborative robotics, and it's as good a lens as any to view AI-Powered Robotics. According to multiple sources, companies working with AI-Powered Robotics tend to ask their robotic systems to provide support in roles that, while they can be automated, still need some amount of human intelligence to execute reliably. The result has been gains across sectors and in both discrete and process manufacturing.

7.1. Collaborative Robotics

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For over a century, robots have provided a means to automate repetitive and dangerous tasks that resulted in increased efficiencies in the workplace but came with a high cost to switch from automated, yet manual, tasks. As firms aim to build flexibility into their operations to keep pace with trends and maintain their competitive foothold, a new trend is emerging where robotics assist human operators. Research is just beginning to formalize the definition of an AI-powered robot. Even though there is no official definition, the intent is to extend classical robotics and design systems that leverage AI model-type behaviors, including complexity, non-determinism, scaling, and prediction. AI-powered robotics are likely to have profound implications on manufacturing work because they embody the idea that human workers and machines are increasingly complementary and interdependent. More and more actions are likely to be automated as AI becomes more capable, particularly for search-based tasks.

Collaborative robotics promise to "produce new high-quality, internationally competitive products," "create and retain high-value jobs," and "significantly enhance overall productivity, production flexibility, product quality, and agility in the mixed model high-mix/low-volume (HMLV) USA manufacturing sector." This section provides a better characterization of the state of collaborative robotics through the analysis of 117 patent filings from Google Patents and others. From this analysis, we conclude that the trend of collaborative robotics has evolved from cobots where the robots are complementary and aid in a shared task but do not physically interact, to what we call co-bots where the extended definition includes the robotics component of "people and machines working alongside each other" or systems characterized by humans and machines working in the same space; to a third class of robots that we call bio-bots that increasingly interact with humans physically. These natural progressions show robots with less "separation" (co-bots versus cobots) and natural robots that interact with humans as required in many high-touch and high-mix manufacturing industries.

8. Conclusion

The global manufacturing industry is in a state of revolution, driven by new business demands on manufacturing, resource constraints, the data revolution, and how manufacturing technologies have matured. Today, U.S. manufacturers continue to spend more on workers' compensation (per unit of payroll or gross output) compared to other major manufacturing economies, such as Germany and Japan. Accordingly, it is imperative for American manufacturers to capture gains in production technology from the automation of process to enable growth opportunities. Automating any process begins with understanding the process itself and the evidence that AI robotics works comes from both the published science and on-site studies where companies have improved improvements in manufacturing processes with productivity gains of 75-120 percent.

This report provides an investigation in the development of AI-powered robotics and how it is being used to address challenges facing the manufacturing industry, such as worker safety and rising healthcare costs related to repetitive motion injuries. It presents innovative technologies for automation that are being applied in production environments. Presented uses include traditional industrial production robots and robotic simulation systems, as well as more cutting-edge autonomous, advanced mechatronic systems using remotely manned operations. A section of the report describes various case studies, along with photographs, technical specifications, and other relevant information. Case studies stem from St. Onge Company, Walmart, Aethon Inc., Schilling Inc., Seegrid Corp., Washington County Career and Technical Center (VT), Seegrid Corp., Rethink Robotics Inc., Rodem, Inc. (AL), and University of Louisville. The report explains how the project was formed and discusses some potential applications for companies interested in testing or use.

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