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Artificial Intelligence in Smart Manufacturing: A Systematic Review on Applications, Future Trends, and Challenges

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Abstract: ***Manufacturing industries profoundly impact the economic progress of any society or country. They hold a Key Asset to our future developments. Our next generation of Industry 4.0, holds the promise of increased flexibility in manufacturing, along with mass customization, better quality, and improved productivity. Smart manufacturing is an emerging form of production and investing in new technological concepts of cyber-physical systems, the internet of things, cloud computing, and artificial intelligence. These advances are rapidly enabling a new generation of smart manufacturing. This systematic review will help to identify how smart manufacturing research is contributing to the development of Industry 4.0 and for a broader perspective about the links between the Cyber-physical systems, Industry 4.0, and Smart manufacturing.***

Keywords: Smart Manufacturing, Industry 4.0, Cyber-Physical Systems, Artificial Intelligence

1. Introduction

1.1 What is Smart Manufacturing?

- Smart manufacturing is a comprehensive classification of manufacturing aiming at improving concept production and product transaction. Manufacturing can be defined as a multistage process that creates a product from raw materials and Smart manufacturing is computer control and high levels of flexibility in cyber-physical processes which include the use of Cyber Intelligence, Machine Learning, and the Internet Of Things.
- Smart manufacturing also means the use of common intelligence for people and machines to influence the ergonomics of manufacturing. Smart manufacturing aims to increase the efficiency of manufacturing resources, improve product design, reduce production waste and thus improve business value and safety, all while meeting customer requirements in terms of quality and reliability.

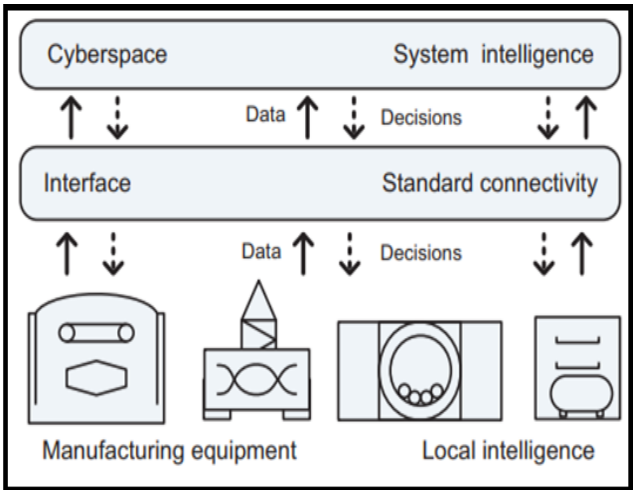

Figure 1: General concept of a smart manufacturing enterprise

2. Theory

2.1 Pillars of Smart Manufacturing and how do they hold for New Development?

1) Manufacturing technology and processes

The development of manufacturing technologies and processes is expected to grow at a faster rate in future years. New materials, components, and products will be used. The best example of the recent trend in manufacturing is Additive manufacturing which is changing the way of making and processing products in the digitalized world and opened the ways for new applications like biomanufacturing. The utilization of processes will increase with the usage of new materials, automated processes, and better quality management of a product. A new generation of affordable robots will improve the efficiency of factory automation. The more upgraded Sensors and latest software capabilities will make the new manufacturing equipment much intelligent and compliant to the processes used and the factory.

2) Materials

Material is a basic component required for manufacturing any particular product and it may well be that smart materials and smart products will follow their development paths. Smart manufacturing will be used all types of materials, including organic-based materials and biomaterials. It is conceivable that landfills will become new mines of various materials. Some new materials will require novel processes that must be developed and incorporated in smart manufacturing. Additive manufacturing alone will be a great contributor to the search for new materials and their mixes.

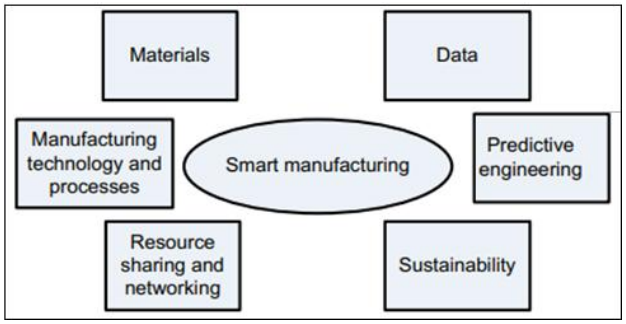

Figure 2: Pillars of Smart Manufacturing

3) Data

Data is the vital pillar of Artificial Intelligence which helps to improvise the methods of quality improvement and is the base of development of smart manufacturing. The robots and AI-driven machines are programmed by the data which builds the foundation of production in the digital world.

4) Predictive Engineering

To increase the productivity of manufacturing products while reducing maintenance costs, it is crucial to develop and implement an intelligent maintenance system that allows manufacturers to determine the condition of working systems to predict when maintenance should be performed.

Predictive engineering is one of the latest additions to the space of manufacturing solutions that will lead to an anticipatory rather than reactive enterprise. Traditionally, the manufacturing industry has focused on using data for analysis, monitoring, and control, e.g. productivity analysis, process monitoring, and quality control. Six sigma and other data-analysis concepts have had a tremendous impact on advances in the quality of manufactured products and services.

However, for the most part, traditional efforts have emphasized the past over the future states of manufacturing processes and systems. Predictive engineering offers a new paradigm of constructing high-fidelity models (digital representations) of the phenomena of interest.

5) Resource Sharing And Networking

Sharing manufacturing and transportation resources across manufacturing chains will become a common practice. Innovation of manufacturing equipment could benefit from resource sharing as companies may purchase equipment based on an explicit assumption that it will be shared. Sharing different data and integrating it with proper algorithms will help connect different sectors to make more efficient and connectible industries which will indirectly help reduce cost and time for the production.

6) Sustainability

AI can use predictive capabilities and intelligent systems to manage the demand and supply and quality management more accurately and help optimize the problem more efficiently which helps to cut costs and unnecessary wastage of raw material. AI, robotics, and other advanced technologies help across many sectors of the economy, e.g., the supply chain, distribution channels, manufacturing, provides a significant impact on the natural environment leading to reduction of pollution, decrease in greenhouse gases emission, decrease in energy consumption and increase in profits, simultaneously.

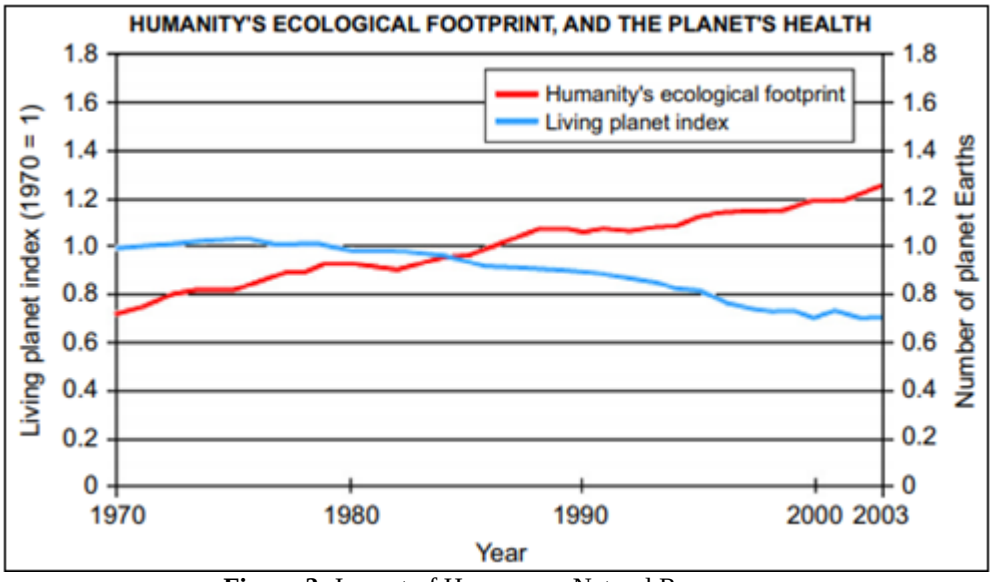

Figure 3: Impact of Humans on Natural Resources

As shown in Figure 3. The utility of natural resources by humans is increasing day by day and we need all possible solutions to decrease the use of natural resources. Smart manufacturing by using the means of AI-driven systems will surely help reduce the carbon footprint by reducing the wastage of raw material. Intelligent manufacturers must take into account all the indicators of energy demands and supply in planning their chain supply and processing strategies. Reduction of waste including energy waste shows not just corporate responsibility, but is also seen to make sound economic sense.

2.2 Applications of AI IN Manufacturing Industries

Artificial intelligence is an essential part of smart manufacturing to enable accurate insights for better process

and decision making. AI's capabilities will reduce or stop outsourcing in the emerging market and bring services in-house. Machine learning has been widely used in different stages of the manufacturing lifecycle covering concept, design, evaluation, production, operation, etc. The applications of cyber-physical systems in manufacturing engineering are widely used in different categories of production processes, operations, fault detection, maintenance, decision support, and product quality improvement.

1) Autonomous vehicles - In the automotive industry, autonomous vehicles have become the trending application of Smart and Intelligent manufacturing. Developers are working overtime to develop AI-driven systems to ensure protection and enable self-controlled cars and trucks. These systems use a wide range of AI-drive technologies, such as deep learning networks, human language processing, and gesture-control features, which provide the brains for vehicles that can safely drive themselves, with or without a human driver on board.
2) Manufacturing - AI-enabled applications are now emerging in all types of manufacturing and not only in the automotive sector. Engineers and developers use AI-driven systems to manage the shop floor, assembly lines, and identification of defects and faults in the manufacturing processes that take place. The emerging AI technology helps reduce costs and time in the production line and overall producing better-finished products for the customers.
3) Quality control - An important part of the production line is the quality of the product before handing it to the customer and AI-driven smart systems are key holders for quality assessment of components. AI system is designed in such a way that it gets better day by day recording the previous data and improvising itself to make sure the quality of the product is best at its level. Diagnosis and prediction of equipment faults will become routine in smart manufacturing. Using predictive analysis methods helps inspect and provide superior quality control on machined parts, micromaterials, and textured metal surfaces.
4) Smart Factory - Smart factory is the emerging and vital component in Industry 4.0. The smart factory is a factory that is accompanied by technologies such as Artificial Intelligence, Smart networking, data analytics, and augmented reality. It mainly combines the physical resources which are integrated with the local factory network which in turn is connected to the cloud network. This cloud is provided with access and control to supervise the manufacturing system. The physical components include real-time machines. The cloud is the storehouse of all the data that is acquired from the physical resources which will be integrated for better results. This data and information in the cloud are operated by the technicians and engineers working in the factory via the terminals to which the data is connected.

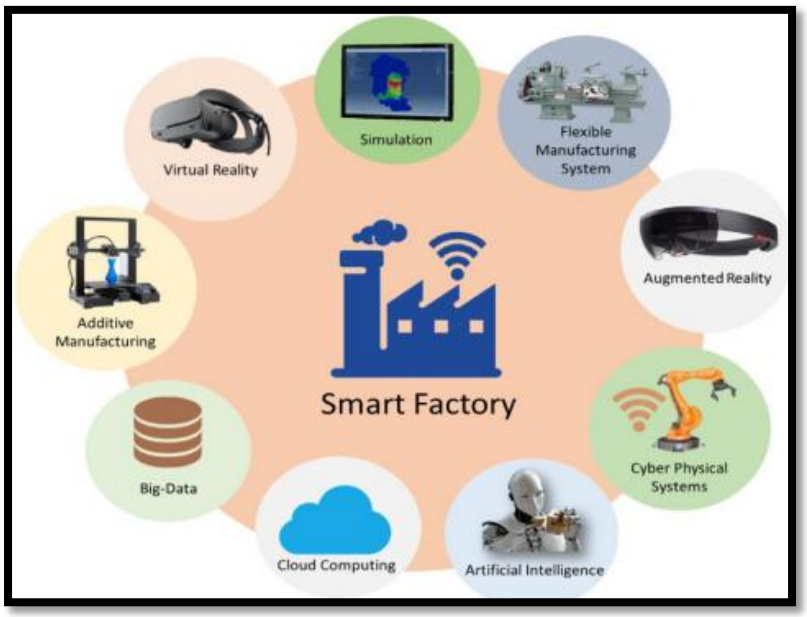

Figure 4: Components of Smart Factory

5) Supply chain management - In today's global economy, automotive manufacturers have extremely complex supply chains that span many geographies. Any glitches or breakdowns in the supply chain can be extremely costly. With AI, manufacturers can gain greater control over their supply chains, including processes for planning, logistics, inventory tracking, and management. For example, AI-driven systems can predict complex interactions between production units and automate requests for parts, labor, tools, and repairs.

2.3 Future Trends and Challenges of Smart Manufacturing

2.3.1 Future of Smart Manufacturing

- Smart manufacturing is full of opportunities and challenges. The greatest challenge might be within the acceptance of the emerging manufacturing reality and alter. A new wave of factory automation will be supported by advanced and affordable robotics. This will help create cyber employment rather than traditional jobs. The 'cyber' part of the smart factory, in itself, is an

enterprise within the enterprise, with job descriptions to be defined and a workforce to be trained by the educational establishments. The better we understand the longer-term needs, the higher the smart enterprise will function.

- AI will impact manufacturing in ways we've not yet anticipated. Nonetheless, we will already check out some more noticeable examples.
- The continued enhancement in computer visualization has long been used for quality assurance by detecting product defects in real-time. But now that manufacturing involves more information than ever integrated with the very fact that plant managers don't want to pay employees to enter information—AI with computer vision can rationalize how information gets apprehended. A mill-hand should be ready to acquire raw materials reserve from the shelf and have the stock transaction created automatically supported a camera observing the method. This will be the natural interface, just completing the task at hand not inputting or scanning things into a system.

2.3.2 Challenges in Smart Manufacturing

Intelligent manufacturing systems are capable to cope up with various challenges and complexities faced by the existing industries, but there still exists some challenges during the implementation of smart manufacturing systems. Based on various dependent variables, intelligent manufacturing systems are considered to be faced by security issues, lack of system integration, lack of return of investment in new technology, and financial issues during the beginning of new smart manufacturing systems and/or during the upgrade of existing industries with new manufacturing technology. The challenges faced by the smart manufacturing systems and their possible solutions are described below.

Security Issues of Artificial Intelligence in Manufacturing

Cyber security and questions of safety will remain a challenge to be continuously addressed. The intelligent manufacturing system means the use of an integrated network system in a manufacturing system for sharing information between manufacturing or machining units to the end customers. For this purpose, it requires network connectivity and is arranged especially through the web . Sharing information through the internet requires the security of data and information throughout the system at various points with global unique identification and end-to-end data encryption. And hence, every node of the network should be protected against external attacks and data misuse. The thing that's most significantly considered while designing the networked systems like smart manufacturing systems is to make sure the safety of the system and therefore the overall process.

System Integration

Another challenge of the implementation of a sensible manufacturing system is that the integration of latest technology equipment with the prevailing ones. The compatibility of existing devices to new devices causes various problems in the implementation of smart manufacturing technologies. The old machinery which is being controlled by some communication protocols could be outdated and new devices may have a special protocol. Also, the machine-to-machine communication and the interconnectivity of the system require a better communication system.

3. Conclusion

Artificial Intelligence in Smart manufacturing will lead the development of the manufacturing industry in the future. The arrival of the knowledge age has triggered the planet wide scientific and industrial revolution and therefore the integration of the world economy. The combination of data technology and modern industry will promote our manufacturing industry to a better level of intelligent development. The future development trend of the manufacturing industry will be "man-machine-intelligent manufacturing". Smart Manufacturing is all about autonomy, evolution, simulation, and optimization of the manufacturing field. The scope of simulation and optimization will depend on the availability of data and data-driven tools. Intelligent manufacturers must take under consideration all the indications of energy and material demands and provide in planning their chain supply and processing strategies. Reduction of waste including energy waste shows not just corporate responsibility but is additionally seen to form sound economic sense. Intelligent manufacturing can make the whole production process more flexible and personalized, and improve the production efficiency, as well as the competitiveness of the industry.

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