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Introduction to Industry 4.0 & The Role of Data Analytics

Bashar Baajour

Abstract

Industry 4.0, also known as the fourth industrial revolution, is regarded by many as the impending future of manufacturing. It utilizes various tools to achieve a considerable advantage over traditional manufacturing techniques. This paper gives a general overview on Industry 4.0 with a particular focus towards data analytics. It specifically highlights the roles of data collection, organization, analysis and actions as part of a smart facility.

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Introduction

1765 was arguably the most significant year for the technological advancement of the human race. Simply put, the invention of the steam engine revolutionized the way humans went on with their lives, and thus was born the first industrial revolution. The steam engine is a rudimentary machine by today's standards; however, it was advanced enough to significantly speed up almost all labor related processes.

Similar to the first industrial revolution, the second, which occurred in 1870, marked the inventions of new impactful technologies. This period saw the creation of the internal combustion engine, advanced communication methods, and fossils fuels as an energy source. Following the same theme, the third industrial revolution, which occurred in 1969, saw the rise of advanced electronics (notably computers) and the exploitation of nuclear energy.

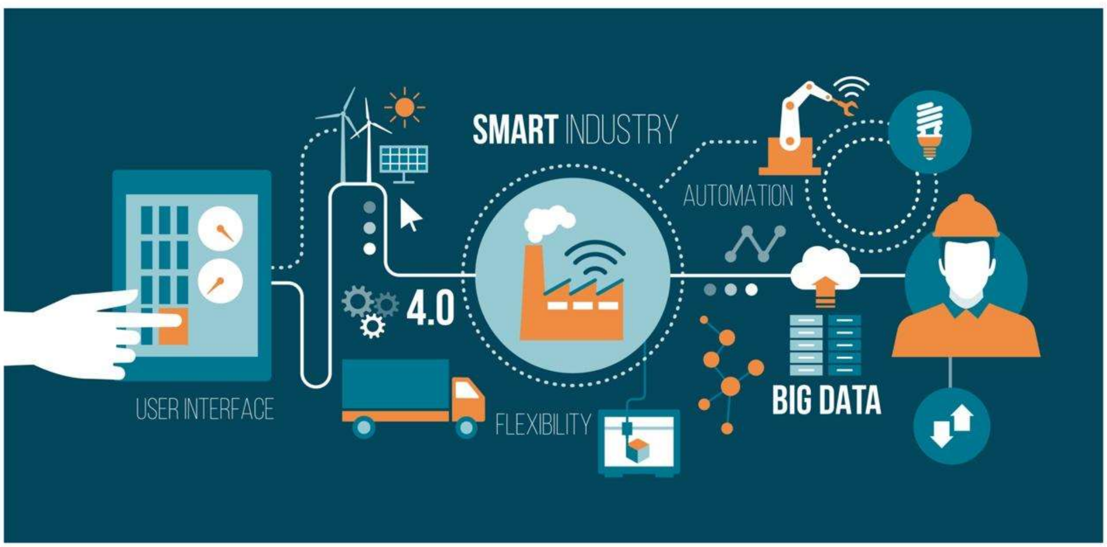
Fast forward to our current day and age. The 21st century marks the dawn of a new age of industry. Given the recent technological advancements in the fields of electronics and telecommunication, the fourth industrial revolution, also known as Industry 4.0, has begun to roll out. Industry 4.0 signifies the transformation of old-fashioned industrial facilities into advanced, flexible, and automated facilities. These autonomous facilities are highly reliant on constantly evolving technologies with the most significant being high-speed communication, data analysis, and machine learning. These facilities are needed now more than ever. The manufacturing landscape, driven by today's consumer, needs high flexibility and the ability to produce customizable products with short life cycles. Industry 4.0 and the promise of autonomous "smart" facilities will change the way manufacturing is approached all around the world.

Benefits and Relevance

Industry 4.0 is seen by many as the future of manufacturing due to its unparalleled relevance in today's market and the tremendous upside it offers over traditional manufacturing techniques. These new facilities are highly efficient, optimized, and autonomous. This is achieved by establishing a connection (often referred to as Internet of Things or IoT platform) between all components and machines in a facility which enables high speed communication between these components. This connection equates to having a steady real time flow of data sourced from all facets of a facility. Large amount of data can be studied using various data analysis techniques to enable an autonomous and efficient system that is, in ideal cases, able to predict and prevent issues that may take place in a facility. Industry 4.0 is highly dependent on the evolution of data analysis techniques and high-speed wireless communication technologies such as 5G and Wi-Fi 6. [5]

There has been a noticeable trend, especially in the consumer electronics industry, towards products with shorter life cycles that are highly customizable but still conform to set regulations. [7] This forces many companies into releasing new versions of products (such as phones and laptops) at least every year. Many of these products are also highly customizable in terms of performance and aesthetics. Therefore, products are volatile and their manufacturing processes are subject to change at any point due to consumer demands. To cater to this trend, companies must compress their overall product cycle time, from development through production. By having a lower product cycle time, manufacturers become better suited to react to any quick market changes, including customization requests.[2] In a market dominated by products following these trends, the need for Industry 4.0 is born due to its capability of driving consistency, flexibility, and efficiency. Smart manufacturing facilities can achieve up to a 40% reduction in product cycle time. [4]

These smart facilities offer an array of advantages over traditional facilities. To begin with, one of the main benefits offered by Industry 4.0 is the unparalleled optimization and efficiency achieved by smart facilities. This highly efficient system mainly stems from the data collection and analysis taking place behind the scenes. This data analysis allows the machines to run



autonomously while also keeping a close eye on the real time data flow to predict and preemptively solve possible issues. This allows the machines to run continuously and consistently. This is similar to how humans foresee events and try to prepare for them. For example, a person who measures their internal temperature on a daily basis will be able to predict sickness from an unusually high temperature. This could prompt them to take medication before the sickness can become serious. The same logic applies for these facilities. The large amounts of data can be a great indication for when machine functions are deteriorating which could cause a dip in efficiency. The data also serves as a basis for making a preemptive prescription to solve that issue. If a facility's system predicted that a certain part is about to break, it could automatically order a replacement for it. This would significantly reduce any potential downtime. With all these factors combined, smart facilities can see a 30% decrease in capital intensity, coupled with added positive effects on energy consumption, yield, waste reduction, and efficiency. [4] In addition, these smart factories can prove more flexible and reliable due to their autonomous nature. A good example would be the Covid-19 pandemic which forces workers to practice social distancing in a factory, which may not be feasible and still maintain safe and productive operations. In this case, a factory that can output products with minimal human intervention could be less susceptible to downtime.

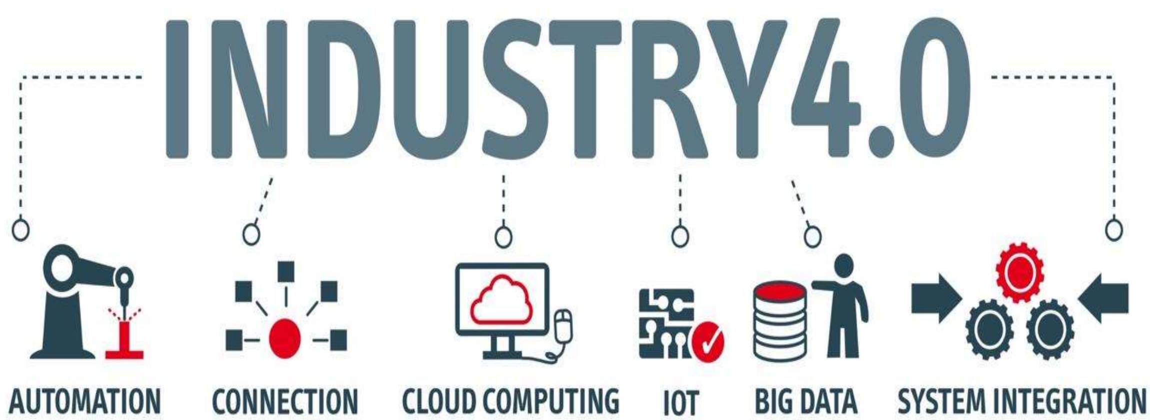
Data Analysis Overview

The goal of Industry 4.0 is to create smart autonomous manufacturing facilities, and one of the main factors in achieving this goal is data analytics. Data analytics is the process of studying data through various means with the goal of extracting new relevant information. The means vary depending on the target of the analysis and the data itself. [8] Industry 4.0 is heavily reliant on multiple types of data analysis. These processes fall into four main types of data analysis which are descriptive, diagnostic, predictive, and prescriptive data analysis, all of which are essential for Industry 4.0. [1]

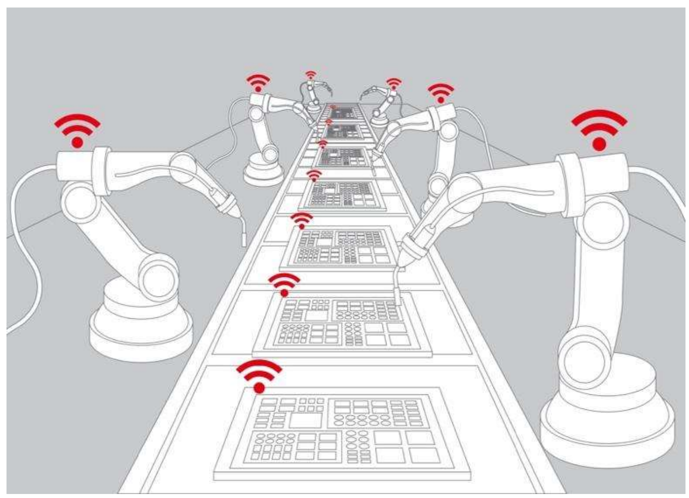
Blueprint of the Overall Data Analysis Process

While industrial data analytics methods may vary, a general blueprint usually begins with the data collection process. Collected data goes through a diagnostic process with the goal of extracting more information from this data. The data is then analyzed to generate predictions. Finally, the prescriptive analysis algorithms process the predictions into preventive action. After this process is finished, the feedback is used for ongoing product innovation and improvement. [4] This is done by gaining information and insights about the products and the manufacturing process from all the data analysis done. Studying this information, which can come in many forms such as trends, can lead to innovation in all areas of production which can give the manufacturer an edge over others.

Descriptive Data Analysis and Data Collection



Descriptive data analysis is exactly what its name implies; it describes the data. In other words, it seeks to answer the question: "What happened?" [1] This represents the first phase of the data analysis process of Industry 4.0. Descriptive data analysis includes the process of collecting data and processing it in simple ways to better suit the processes that come next. The first step to analyzing data is to acquire the data itself, and this is where industrial process monitoring, also known as IPM, comes into play. IPM is the process of monitoring all relevant aspects of a facility. This is usually done using sensors which are connected to the majority of a facility's machines to acquire data. [6] These sensors are specifically chosen to provide data regarding a machine's relevant parameters. For example, machines that are prone to overheating probably have a thermometer within them. In this case, temperature is considered a relevant parameter which explains the need for a thermometer. In addition to that, these sensors are connected to each other and are referred to as a wireless sensor network, or WSN for short. The WSN emulates an Industrial Internet of Things (IIoT) in which all these sensors are connected to one another and can communicate with each other. [3] Technologies such as 5G and WiFi-6 are key to smart factories due to their hyper fast, low latency wireless connection capabilities. With all the machines being connected to one another, a real-time flow of data is established. This data is still considered as "raw data" which needs further analysis in order to extract relevant information.



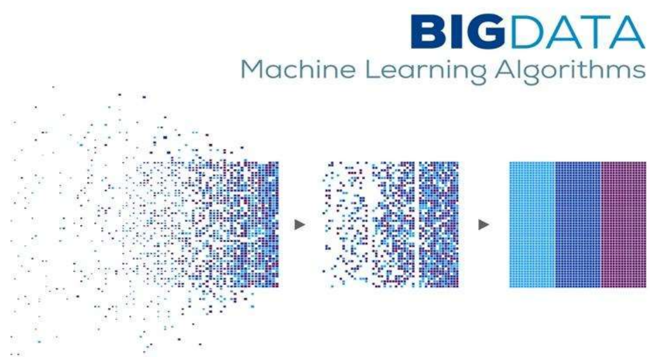
Diagnostic Data Analysis

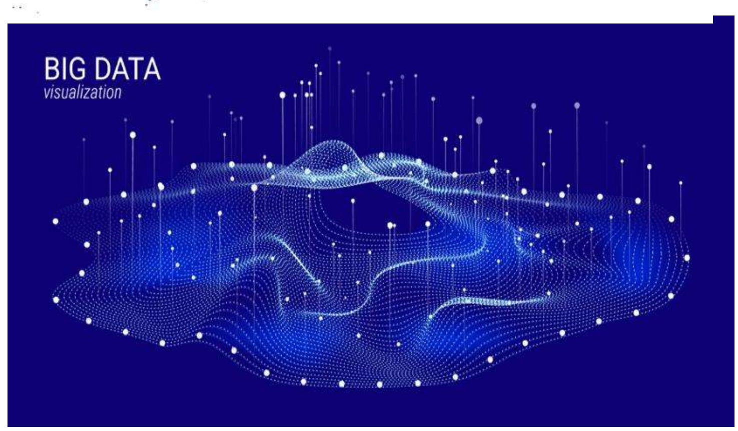
The next step in the data journey is diagnostic analysis. Diagnostic analysis seeks to answer the question "Why did this happen?" [1] Diagnostic analysis is used to locate causes for any issues or data fluctuations. This helps the IoT network in a smart facility to understand the implications of fluctuations in a single machine on other machines or the facility as a whole. In turn, this added understanding of data samples allows the contextualization of data within a facility. This can help further categorize the data with the goal of transforming it into easily consumable data sets for the upcoming data analysis processes.

Predictive Data Analysis

Now that the facility is generating categorized data in real time, the important role of predictive analysis comes into play. Predictive analysis is a form of data analysis that takes data as input and outputs a prediction. This step is extremely crucial for the Industry 4.0 data analysis process since it ensures that problems can be foreseen and prevented before they occur. Predictive analysis can be done in multiple ways, usually involving some form of artificial intelligence. One of the most popular methods for predictive data analysis is data mining. Data mining is the practice of predicting events from patterns found in large amounts of data, known as big data. These data patterns are usually followed by similar events making them suitable for making predictions. For example, if a sharp increase in temperature keeps causing dips in the efficiency of a particular machine, then the data mining algorithm would start predicting a dip in efficiency whenever the temperature rises in that machine. In reality, these facilities and algorithms are far more complicated. Data mining is considered part of the unsupervised learning sub section of artificial intelligence. This is due to the fact that the algorithm is tasked in finding patterns in data with no specific goal in mind. This method is highly effective and does not need data categorization that from the diagnostic analysis step, but has the drawback of large computational and storage requirements. However, another type of artificial intelligence, known as supervised learning, can also prove useful in an industrial setting. Supervised analysis methods rely on a fixed model that is generated from the diagnostic analysis step. The model is fed labeled data as input to generate

predictions as output. Furthermore, the predictions made by supervised learning algorithms are usually different than the ones made by data mining algorithms. For supervised learning, predictions are made for a specific output that is determined by the model. Suppose a supervised algorithm is trained to take w and x as inputs to output y and z. This algorithm would then only operate properly if it is given data samples of w and x, and in that case, it would produce predictions for y and z. On the other hand, data mining does not differentiate between input sets, and returns varied predictions. This makes data mining the more suitable option for general predictive analysis in a smart facility that is trying to predict potential issues. Supervised learning algorithms prove useful when used to predict specific key factors that may lead to production issues.





Prescriptive Data Analysis

One of the attributes of a smart manufacturing facility is to preemptively take actions to avoid possible issues. To do that, the final step of the Industry 4.0 data analysis process comes into play. Prescriptive analysis is a type of data analysis that tries to prescribe a solution to a problem. It uses the results of all previous analysis methods to properly come up with a solution to any problem that may come up. First off, it uses the prediction made by the predictive analysis process to pinpoint future issues. It also uses all the analyzed data from the descriptive and diagnostic analysis processes to come up with solutions. The prescriptions are generated through various methods which include artificial intelligence algorithms, simulations, and modelling. Prescriptive analysis is really what gives these smart facilities their names, since it emulates the decision-making skills of a human that is exposed to large amounts of data. Making the right decisions in real time is what makes Industry 4.0 facilities so optimized and efficient.

Conclusion and the Future of Industry 4.0

Data analytics is a key enabler of Industry 4.0. The advent of gigabit connectivity technologies like 5G and WiFi-6 will allow the amount and speed of data collected to increase by orders of magnitude. Data analysis and the recommended actions that it will produce will be greatly enhanced by ongoing advancements in compute capabilities, both at the edge and in the cloud. All the pieces are coming into place to enable smart, manufacturing capabilities to match the modern products and services that consumers are demanding.

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About the Author

Bashar Baajour

Bashar interned at Joun Technologies. He is a computer engineer who specializes in software development. Bashar is well versed in many facets of software development (such as data science, app development, etc.), and has worked on many projects relating to these topics. He is a firm believer in the importance of learning through experience and growing on a professional and personal level.