ME 338 Term Paper: Application of Data Science in Manufacturing Industry

Swapnoneel Kayal
200100154

Abstract

Businesses across industries have realized the importance of using data, which has led to a growing demand for data science. It is an interdisciplinary field that uses various scientific methods, math, statistics, artificial intelligence and advanced analytics to gain knowledge about structured and unstructured data across a broad range of application do-mains. It can explain how digital data is transforming businesses while helping them to make sharper and critical decisions. It is capable of adding value to any company in any industry who can use their data well. Currently, data science is being used in health care, governments, cyber security, mechanical, aerospace, and in several other industries. The modern manufacturing industry, also known as industry 4.0 [1] uses data science for increasing its productivity, reducing energy costs and boosting production. In today's manufacturing systems, a large amount of data is generated in different volume, velocity and variety of kinds. Data science provides manufacturers with valuable insights regarding profit maximization, risk minimization, large scale processes and speeding up execution time.

1 Introduction

1.1 What is Data Science?

Data science is the study of data with the goal of gaining insightful information for businesses. In order to examine enormous volumes of data, this interdisciplinary approach incorporates ideas and methods from the domains of mathematics, statistics, artificial intelligence, and computer engineering.[2]

A data scientist leverages this analysis to ask and answer questions like what occurred, why it happened, what will happen, and what can be done with the outcomes etc.

1.2 What is Manufacturing?

Manufacturing is the process of creating or producing items with the use of resources such as labor, machinery, tools, etc. It is the fundamental component of the economy's secondary sector. The phrase may be used to describe a variety of human endeavors, from handcraft to high-tech, but it is most frequently used to describe industrial design, in which primary sector raw materials are transformed into completed commodities on a big scale. Such items may be sold to other manufacturers for use in the development of more complicated products, or they may be delivered to end users and consumers through the tertiary sector. [3]

1.3 How can data science impact manufacturing?

The manufacturing industry is undergoing tremendous alterations at the moment. Because of the fast rise of the digital world and the widespread use of data science, several human activity domains are striving for advancement.

Every day, the amount of data that must be saved and processed grows. As a result, today's manufacturing organizations must discover new solutions and applications for this expertise. Data benefits manufacturing organizations by allowing them to automate large-scale operations and reduce implementation time. There have already been several instances of data science applications that have become widespread in manufacturing and provided advantages to producers. [4]

Figure 1: Data Science Applications in Manufacturing Industry

2 Data Science Opportunities in Manufacturing

2.1 Predictive Analytics

Predictive analysis is the process of using past data to anticipate and avert problematic circumstances. The success of the company and how it operates are of great importance to the manufacturers. Finding the ideal way to interact with problematic circumstances, get around obstacles, to stop them from happening is a wonderful opportunity for manufacturers that use predictive analysis. Waste management that includes overproduction, idle time, logistics, inventory etc. is made feasible with the use of predictive analytics. [5]

2.2 Fault prediction and preventive maintenance

Both of these prediction models seek to foresee the time when a piece of equipment will stop working as intended. As a result, a secondary goal can be achieved, which is to limit or completely stop these failures. This is possible because of the different forecasting techniques. Preventive maintenance is often performed on an equipment that is still in use in order to reduce the risk of a breakdown. There are two basic forms of preventive maintenance: time-based and usage-based.

Preventive maintenance's greatest strength is planning. If a prognosis of probable equipment issues is known, the manufacturer can plan a break or a shutdown for repair. Such breaks are typically used to avoid large delays and mistakes brought on by potentially more serious problems. [6]

2.3 Price Optimization

Various aspects and criteria that affect the product's pricing must be taken into consideration while manufacturing and selling the item. Up until the cost of distribution, all costs, starting with the initial cost of the raw material, continue until the ultimate cost of the product. If the price turns out to be too high then no customer would want to buy and similarly if the price is too low then there would be hardly any profit left for the manufacturer. Hence, the price must be optimal for both the parties.

Producers and consumers use price optimization to deter-mine the best feasible price that is neither too high nor too low. Modern pricing optimization techniques will effectively increase your profits. This is possible because these leverage pricing and cost information from internal sources of your competitors while also extracting optimum price variations.

Therefore, price optimization becomes extremely important and is a process that develops continuously under the conditions of a highly competitive market and changes in client requirements. [12]

2.4 Demand Forecasting

Demand forecasting is a dynamic process that needs knowledge processing which requires a lot of work and expertise from the finance team. Additionally, it appears to be closely related to inventory control. This is due to the fact that demand forecasting uses supply chain data.

There are several benefits to the market outlook for producers. First of all, it enables better inventory management and lessens the need to handle significant amounts of worthless things. The tool for online inventory management helps in gathering data for additional research that might be very beneficial for a multitude of reasons. The ability to continuously update the data supplied for demand forecasting is another crucial component. As a result, accurate projections may be formed. The enhancement of supplier-manufacturer relationships offers further advantages since both parties can effectively manage their inventories and supply chains. [12]

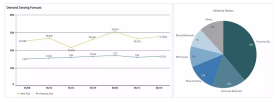

Figure 2: Demand Sensing Forecast

2.5 Warranty Analysis

Manufacturers spend a lot of money each year defending warranty claims. Useful information on the product's consistency and durability may be found in the warranty statements. They display any early warnings or flaws in the product.

Using this information, the company may modify current items or develop new ones that are more effective and efficient. Modern warranty analytics solutions assist providers in processing massive amounts of warranty-related data from various sources and applying it to determine where and why warranty problems are occurring. [12]

2.6 Robotization

Robots are changing how production is done. They are frequently used nowadays to carry out mundane activities as well as those that might be dangerous or challenging for humans.

Manufacturers have started investing more and more money in robotizing their businesses since AI-controlled robot models assist in meeting the rising demand. Additionally, industrial robots principally help to raise the product's quality. Every year, the improved models flood the factory floor, revolutionizing the assembly lines. Additionally,

manufacturing robots for businesses have become more in-expensive than ever. [12]

2.7 Product Development

Manufacturing organizations now have tremendous opportunities for new product development owing to “Big Data”. Big Data is a benefit that manufacturers utilize to better understand their consumers and meet their demands. Data may hence be used to create new goods or enhance old ones.

Big Data may be used by manufacturers to build products with increased customer value and simultaneously lower the risks associated with launching a new product. Actionable observations are taken into account while modelling and planning. This information can aid in better decision-making. In order to enhance the operational elements of the distribution chain, data management approaches are often used. [12]

2.8 Computer Vision Applications

Computer vision applications and AI-powered technologies started to find utility in development during the quality control stage. This area has shown great success with object identification, object detection, and classification. Individuals often do quality management monitoring. But nowadays, using computer vision instead of human eyesight has become more common. Such control systems often include computers, cameras, and illumination for picture capturing. Afterwards, these photographs are algorithmically compared to the standards to spot deviations. [7]

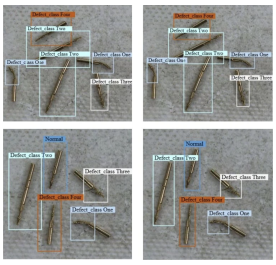

Figure 3: Defect Detection using Computer Vision

The following are the primary advantages of computer vision applications:

- Quality control monitoring
- Decrease in the cost of labor
- High-speed capability for production
- 24/7 continuous operability

3 Market for Data Science in Manufacturing

“The Big Data Analytics in Manufacturing Industry Market was valued at USD 904.65 million in 2019 and is predicted to reach USD 4.55 billion by 2025, at a CAGR of 30.9 % over the forecast period 2020–2025, according to one estimate for the US”. [8]
According to a different estimate, "TrendForce projects that by 2020, the worldwide market for smart manufacturing solutions would be larger than US $320 billion”. [9]
According to a recent analysis by Grand View Research, Inc., the size of the worldwide smart manufacturing market is predicted to reach USD 395.24 billion by 2025, registering a CAGR of 10.7 %. [10]

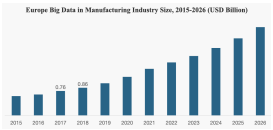

Figure 4: Big Data in Europe’s Manufacturing Industry

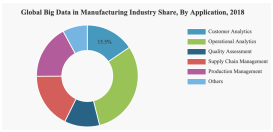

Figure 5: Big Data in Global Manufacturing Industry

4 Issues with using Data Science in Manufacturing

4.1 Lack of subject matter expertise

The study of data is a very novel field. Every application of data science involves a unique core set of abilities that are extremely necessary. Similar to other industries, manufacturing places a high value on understanding business principles, supply chain elements, and manufacturing and process terms. Hence with insufficient subject matter expertise, the incorrect problems would get addressed, which would eventually result in unsuccessful initiatives and, more crucially, a loss of confidence. [11]
The following figure demonstrates the role of a manufacturing data scientist :

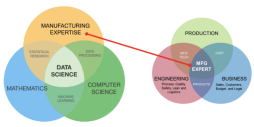

Figure 6: Role of a manufacturing data scientist

4.2 Reinventing the wheel

In a manufacturing setting, every issue is distinct, and also the stakeholders vary. It's hazardous to implement a conventional solution since it will inevitably fail at some point. Every new issue has a portion of its answer that is already in existence, while the other half has to be developed. For the simplest scenario, engineering entails building new ML model workflows and writing new ML packages, and for the most difficult cases, developing a new sensor or piece of hardware. [11]

5 Tools used by a manufacturing data scientist

For every project, a manufacturing data scientist is required to employ a variety of technologies. These include:

5.1 Feasibility study

A feasibility study is a thorough evaluation that takes into account all of the important factors of a proposed project to ascertain the chances of success.
Tools Used: Notebooks (R markdown & Jupyter), GIT and PowerPoint

5.2 Proof of concept

A proof of concept is used to assess the viability of an idea or to confirm that it will work as intended.
Tools Used: R, Python, SQL, PostgreSQL, MinIO, and GIT

5.3 Scale-up

To scale up would be to increase or repeat small-scale efforts in order to expand an intervention's efficacy and reach more people.
Tools Used: Kubernetes, Docker, and GIT pipelines [11]

6 Conclusions

The use of data science in manufacturing is still quite young. Every day, new applications are found, and new solutions are continuously developed. Over time, ROI (Re-turn on Investment) is attained in many manufacturing initiatives (capital investments) that can take somewhere up to 5 - 7 years. Most data science initiatives that are properly implemented achieve their ROI in less than a year. This is the primary reason why they are valued so much. Manufacturing companies are presently utilizing a variety of techniques including data science to help them reach their JIT (Just in Time) target. As a manufacturing data scientist, it is expected to take the time to comprehend the problem statement, aiming for the easy targets, achieving those quick wins and building a sense of trust within the organization.

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