IJCSE International Journal of Computer Sciences and Engineering Open Access
Survey Paper Vol.-7, Special Issue, 7, March 2019 E-ISSN: 2347-2693

A Study of Machine Learning and IoT in Manufacturing industries

R.R. Gore[1*], J.D. Patil[2]

[1]Dept. of Computer Science, Savitribai Phule Pune University, Pune, India
[2] Dept. of Electronics & Telecommunication, Savitribai Phule Pune University, Pune, India

Corresponding Author: rahul.ravi.gore@gmail.com

Available online at: www.ijcseonline.org

***Abstract*—** The last decade has witnessed a shift in manufacturing processes from basic automation and event control to smart systems that create virtual blueprint which is transformed into real-world product. This transformation, dubbed as Industry 4.0 is an optimization of the practices which took place previously in the industries. The driving force behind this revolution has been machine learning and Internet of Things (IoT). Internet of Things is a term for devices that have the capability to connect and collaborate amongst themselves to minimize human intervention. In order to further enhance this connectivity, machine learning techniques are being implemented, that enable decision making through data analysis. This paper aims to demonstrate the use of these techniques in the manufacturing industry in the context of Industry 4.0. It will also shed light upon some of the upcoming applications of the same, including intelligently forecasting the estimated demand, detecting the anomalies within the product, optimizing manufacturing processes and securing the entire framework. The future use cases of this technology will be addressed in this paper.

***Keywords*—** Machine Learning, Internet of Things, Industry 4.0, Manufacturing, Data Analytics

I. INTRODUCTION

Industrialization was embarked by the confluence of various economic factors like availability of resources, conducive market and prospect of better quality of life. The first Industrial revolution which took place in the 18th century was characterized by the discovery of potential of steam, which had a great impact on production and trade. Transportation improved in a manner that was unforeseen. The requirement of manual labor saw a great decline, thus increasing the production manifold.

The second Industrial revolution was a phase of extensive industrialization which saw the advent of use of electricity as a form of energy. This period that began in the late 19th century to the beginning of the 20th century was marked by innovation in the way production took place. Assembly lines took over the former production process. The massive electrification operation led to improvement in mobilization, vast improvement in working conditions and reduction in hazards due to fires and gas leaks. The enhancement in various applications such as mining, petroleum refining and defense technology was undeniable.
Although the preceding developments were extraordinary, the introduction of computers added a new dimension to the manufacturing industry, thus fostering the Third Industrial revolution. Also known as the Digital Revolution, it was the shift from analogue electronics to digital electronics, which commenced from the 1950s and continued throughout the latter half of the 20th century. A multitude of inventions took place in a relatively short span of time, such as the computer, television, Internet and recently the smartphones. Automation of manual tasks and tremendous improvement in communication are the key attributes of this era.

With the dawn of Industry 4.0 the dream of Smart factory has been brought to reality. This is possible due to technologies like cyber-physical systems, cloud computing and cognitive computing. ‘Industry 4.0’ rose to prominence in 2011 from a project of German government. The core concept of this revolution lies upon the principles of Interconnection, Information transparency, Technical assistance and Decentralized decisions. The benefit of Industry 4.0 is that intelligent networks are being created throughout the value chain by connecting machines, work pieces and systems that can control each other autonomously.

Although the idea of Industry 4.0 is in the nascent stage, it has the potential to bring about massive disruption in the manner in which the industries are being operated. One of the driving forces behind this concept is the ability to continuously evolve from massive amount of data that is generated by the processes within the industry, which is a direct outcome of Machine learning. It consists of algorithms in which a mathematical model is built from the sample data, known as "training data". On the basis of this model the machine can make Decentralized decisions without any human intervention. Also the system can provide Technical assistance to humans based on the knowledge acquired from data analysis. Machine Learning has helped to create intelligent devices but they are still isolated due to which it is difficult to harness the power of interconnectivity.

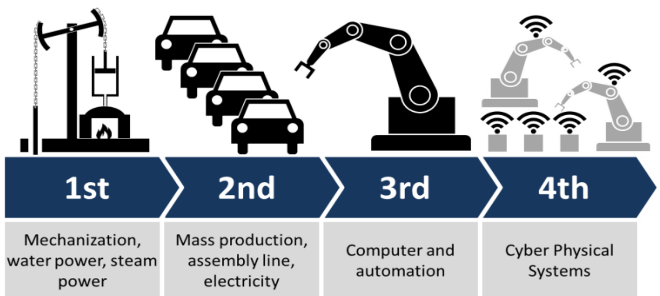

Figure 1: Evolution of industries

Ultimately, it is the digital network of these devices which connect, interact and share data that leads to the true power of Industry 4.0. This is made possible due to the Internet of Things. It can be defined as 'system of interrelated computing devices that have the ability to exchange data over the network'. IoT involves extending the connectivity to various equipment within the industry, which traditionally did not have networking abilities. The seamless integration of such devices leads to rapid increase in the rate of production, dynamic response to unexpected events and real time optimization of the processes. The applications of IoT in manufacturing industry are so abundant, that a separate field, termed as 'Industrial Internet of Things', has originated. The existing manufacturing corporations are creating new business models to incorporate these technologies and investing heavily in research in these fields, in order to guarantee future success. In this paper, we study some of the techniques and applications that have emerged in these realms and will be a crucial part of the Industry 4.0.

Rest of the paper is organized as follows: Section II contains motivation for conducting this study, Section III discusses various methodologies that have been analyzed, Section IV sheds light upon the various challenges faced by the industry and Section V concludes the survey with future direction.

II. MOTIVATION

IoT and Machine Learning has laid the foundation for the technological advancement in the manufacturing industries. Some organizations are investing into research for discovering applications that make use of these technologies. However, there is still a lot to explore in this realm. Our motivation for conducting this study is to create awareness about the existing initiatives and to encourage the readers to assimilate this learning to make the industry smart.

The following techniques have been discussed in this study:

1. Anomaly Detection in Product
2. Process monitoring
3. Predictive maintenance
4. Machine learning to secure IoT system

III. METHODOLOGY

A. Anomaly Detection in Product

The importance of visual quality of a product is undeniable, therefore surface quality inspection is of utmost importance. This is traditionally a manual task, however, due to its monotonic nature, errors may creep in. Also, inspection is subjective in nature and varies from person to person. Thus, automation is desirable in this job. This is achieved using Deep Learning techniques [2]. To detect the surface defects, a convolutional neural network is used for patch-wise completion of surface images.

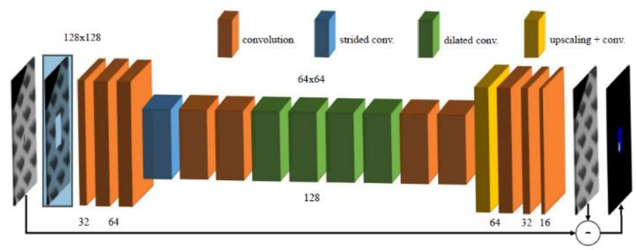

Figure 2: Sample representation of the proposed algorithm

Image completion, aims to automatically fill in a missing portion of an image in a content-aware way. This forms the basis of Anomaly detection in this study. The image completion network consists of a fully convolutional neural network adapted from [8] and [9], consisting of multiple layers where each layer can be described as *Conv (k, d, s, c)* where kernel size is $k*k$, dilation rate is d, stride is s and c denotes the output channels. High resolution surface images are captured and image patches are extracted from them. Data augmentation on these patches is carried out which may lead to unwanted border effects. Therefore, patches of larger size are extracted, augmented and then center-cropped to the target size. These patches are corrupted by masking of the central area ensuring the ratio between known and unknown image content. These patches are then fed to the image completion network. The reconstructed image thus obtained is now compared with the query image to obtain the absolute pixel difference. This pixel difference represents the anomaly. However, only the central part of this difference is considered as the border defects have the tendency to be inaccurate.

Hence, anomaly detection using machine learning not only enhances accuracy, but also reduces human effort.

B. Industrial Process monitoring

In most industrial process control systems these days, process parameters are regularly collected and communicated to gateways, controllers, and workstations. Data analytics frameworks process this data and generate valuable statistics. However, such a framework often faces performance issues, thus consuming considerable amount of time. In addition, the ever-increasing number of IoT devices has resulted in the exponential growth in the volume of data. Real-time data analytics is the answer to this problem. It is designed with the aim to stream, store, operate and envision a tremendous volume of real time data flows collected from multiple nodes, and respond to the control system and operators in a real-time manner.

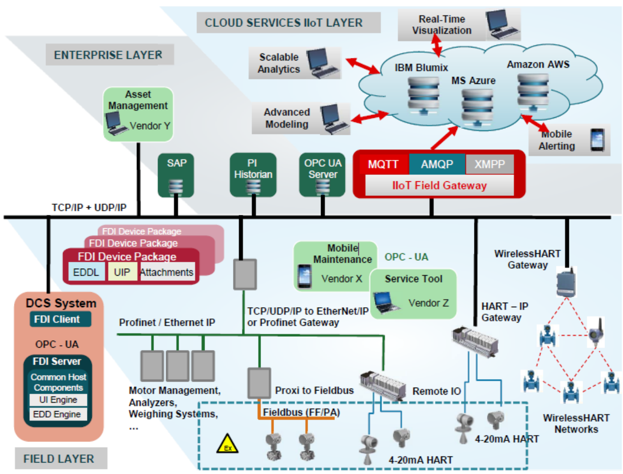

Figure 3: Vision of the Industrial IoT in process industries

The key components of a real-time data analytics framework are: various industrial IoT field gateways for connecting to diverse plant resources, a run-time execution engine for real-time data processing, a distributed database for improving the speed of data operations, analytics models, and a rich set of web services for user interaction [3]. The IIoT gateway provides a common interface for plants that rely on a variety of protocols. The timeseries data thus gathered will be transferred through the framework using a unified messaging protocol. This data is fed to a runtime execution engine that is a combination of a data-flow system and a parallel processing unit. The knowledge inferred from the execution engine is either fed back in the form of alerts or stored in the database for further computation. The web server acts as a visualization platform that can serve the purpose of providing user interaction.
Thus, the combination of machine learning and IoT makes it possible to perform real-time analysis of the day-to-day processes that are a part of the manufacturing industry.

C. *Predictive maintenance*

Conventionally, maintenance of equipment took place in two ways: reactive and preventive. Reactive maintenance basically focuses on carrying out repairs after breakdown, resulting in long periods of downtime. On the other hand, preventive maintenance comprises of tasks for servicing the devices after a fixed time interval or after certain cycles of operations. However, this technique does not take into account the actual health of the device. In order to address the various fallacies in the preceding approaches, predictive maintenance has been introduced [6]. It combines the data gathered from the instruments with machine learning capabilities in order to precisely anticipate whether maintenance is required, and carry out repairs accordingly. Predictive maintenance can be either diagnostic or prognostic in nature.

Devices and systems within the industry generate a vast amount of data. Monitoring this data can give us a lot of understanding about the condition of the system. Therefore, sensors are used to keep track of the machine under consideration. The data is obtained in timeseries format, then sent to the cloud. Various data analysis methods such as clustering and supervised model training are used to gather insights from the data.

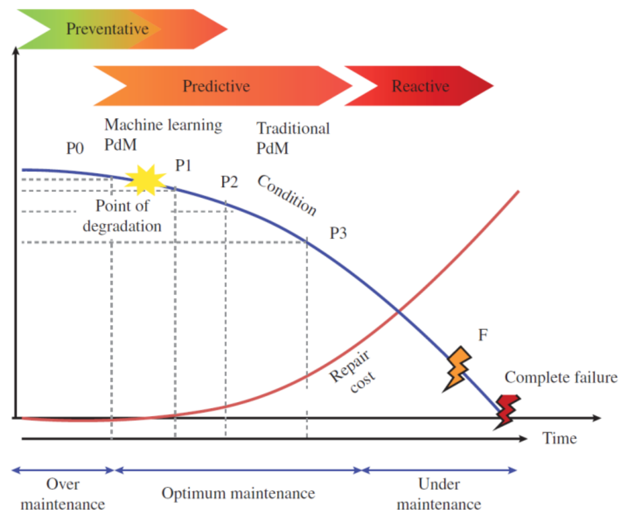

Figure 4: Enhanced P-F interval curve, which is adapted to detect potential failure earlier in the curve via predictive maintenance.

Here, we will consider the example of use of predictive maintenance in a slitting machine in order to predict the possible failures and quality defects, thus improving the overall manufacturing process [7]. This machine has 14 arms (7 on each side) which produce variable sized packaging rolls from a huge wound roll. During the functioning of the machine, the tension and pressure are the key factors that determine the degradation of the packaging roll. These parameters are recorded by the PLC present on the machine, which are then transferred to the IPC (Industrial Personal Computer) which, in turn, is passed on to the cloud. The ARIMA (Autoregressive integrated moving average) prognostic model is used to predict future values. This model is fitted on the data previously collected and future points are predicted which may indicate the state of failure.

In this manner, predictive maintenance can optimize the cost required for servicing the devices while also reducing the downtime.

D. Machine learning to secure IoT system within manufacturing:

With Industry 4.0 every device is interconnected, forming a network which may be wired or wireless. Although this has numerous advantages, it raises the question of security. Heterogeneity within the system and the enormous quantity of devices are the foremost challenges while implementing security within this network. The proposed solution to this concern is the use of machine learning techniques.

All the devices within the network can be categorized as edge devices and gateways. The edge devices are basically low power appliances which consist of sensors and actuators; gateways connect multiple edge devices at a time with the internet and aggregate the data. Using deep learning within the IoT gateway, it is possible to enhance the security of the system.

Initially, a machine learning model is trained on the data based on normal operations, received from the sensors [5]. The training data consists of factors such as time stamp, device ID and sensor value. These parameters can be used to distinguish between regular and irregular data. Once trained, the model can detect the abnormal data, which is an indication of breach of security. For example, if the value received from the sensors does not lie within a specific range, or the difference between the timestamps, indicating time interval, is inconsistent, it could be a sign of infringement or intermittent attack. Thus the use of machine learning within an IoT gateway can offer the foundation for a more secure manufacturing infrastructure.

IV. Challenges and Gaps

As discussed, the introduction of IoT and Machine Learning can definitely bring about great improvements in the manner in which the manufacturing industries function today. However, it comes with its own share of difficulties. Since, IoT and Machine Learning are highly specialized fields, very few people possess the requisite knowledge. Hence, it is difficult to find people who are skilled enough. In order to carry out the analytics, large amount of data is required. But not only the quantity, the quality of the data also plays a huge role in determining the success of the Machine learning algorithms. With industry 4.0, the machinery used for production will already have smart technologies imbibed in them. However, the existing devices or machinery must be retrofitted with smart sensors to enhance their capability. This is easier said than done. Also, the devices in the IoT network have to be continuously interconnected in order to function properly. The major problem occurs in case of remotely located devices where connectivity is sparse. Although, these problems have not been addressed completely till date, these must be taken into consideration as we proceed towards the common goal of Industry 4.0.

V. Conclusion and Future Scope

This study looked at the ways in which the industry has evolved and the practices that were initially implemented within the industry. Further, it delved into the applications of utilization of machine Learning and IoT to understand the underlying benefits. Addressing the importance of visual quality and suggesting an approach which automates the surface inspection is the idea of “Anomaly Detection in Product”. Under “Industrial Process monitoring” a novel way to survey the data generated by various jobs within the industry is studied. The significance of maintenance and the ability to speculate the occurrence of failure has been discussed in “Predictive maintenance”. Lastly, “Machine learning to secure IoT system within manufacturing” explores the concerns of security in the industrial framework.

The digital transformation of manufacturing industry is still in the elementary stage; many areas still remain unexplored. One good example of this is using deep learning techniques efficiently at the edge device itself. This will have substantial consequences, as latency caused due to transfer of data over network will be brought down and power consumption can be optimized. Automation has already brought about universal reformation by means of smartphones, robotics and Internet. Industry 4.0 promises to bring about a similar change in the manufacturing industry.

References

[1] S.K. Bose, B. Kar, M. Roy, P.K. Gopalakrishnan, A. Basu, "ADEPOS: Anomaly Detection based Power Saving for Predictive Maintenance using Edge Computing." arXiv preprint arXiv: 1811.00873, **2018.**

[2] M. Haselmann, D.P. Gruber, P. Tabatabai, "Anomaly Detection using Deep Learning based Image Completion." arXiv preprint arXiv:1811.06861, **2018.**

[3] S. Han, T. Gong, M. Nixon, E. Rotvold, K.Y. Lam, K. Ramamritham. “RT-DAP: A Real-Time Data Analytics Platform for Large-scale Industrial Process Monitoring and Control.” arXiv preprint arXiv: 1802.07855, **2018.**

[4] G. Li, X. Yang, D. Chen, A. Song, Y. Fang, J. Zhou, “Tool Breakage Detection using Deep Learning” arXiv:1808.05347, **2018.**

[5] J. Canedo, A. Skjellum, “Using machine learning to secure IoT systems”, 14th Annual Conference on Privacy, Security and Trust (PST), **2016.**

[6] R.B. Shetty, "Predictive Maintenance in the IoT Era." Prognostics and Health Management of Electronics: Fundamentals, Machine Learning, and the Internet of Things, **2018.**

[7] A. Kanawaday, A. Sane, "Machine learning for predictive maintenance of industrial machines using IoT sensor data." Software Engineering and Service Science (ICSESS), 8th IEEE International Conference on. IEEE, **2017.**

[8] S. Iizuka, E. Simo-Serra, and H. Ishikawa, "Globally and locally consistent image completion," ACM Transactions on Graphics, vol. 36, no. 4, pp. 1–14, **2017.**

[9] J. Yu, Z. Lin, J. Yang, X. Shen, X. Lu, and T. S. Huang, "Generative image inpainting with contextual attention.", arXiv preprint, **2018.**

Authors Profile

Mr. R R Gore pursued Bachelor of Engineering from Savitribai Phule Pune University in year 2018 in the Department of Computer Science. He is currently working as an industry professional. His areas of interest include Data Science, Machine Learning, Cloud Computation, Internet of Things and Product Lifecycle Management.

Ms. J D Patil pursued Bachelor of Engineering from Savitribai Phule Pune University in year 2018 in the Department of Electronics and Telecommunication. She is currently working as an industry professional. Her areas of interest include Data Science, Machine Learning, Cloud Computation, Internet of Things, Embedded Technologies and Product Lifecycle Management.