Scope of Machine Learning for Mechanical Engineering

MAJOR PROJECT SYNOPSIS

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By

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INTRODUCTION

Mechanical engineers are both consumers of machine learning and critical facilitators of it. As we design and apply machines and employ applied physics in bio-medical devices, transportation technology, manufacturing and myriad other areas, machine learning is critical in the implementation of practical technology and an important element in providing better, smarter results.

Manufacturers are always keen to adopt technology that improves product quality, reduces time-to-market, and is scalable across their units. Artificial Intelligence, Machine Learning, and Robotic Process Automation are helping manufacturers fine-tune product quality and optimize operation.

Mechanical engineer has many tasks to do in the organization be it in the production department, quality assessment department, sales and marketing and more. In any of the department automation can be implemented by making the use of machine learning and artificial intelligence
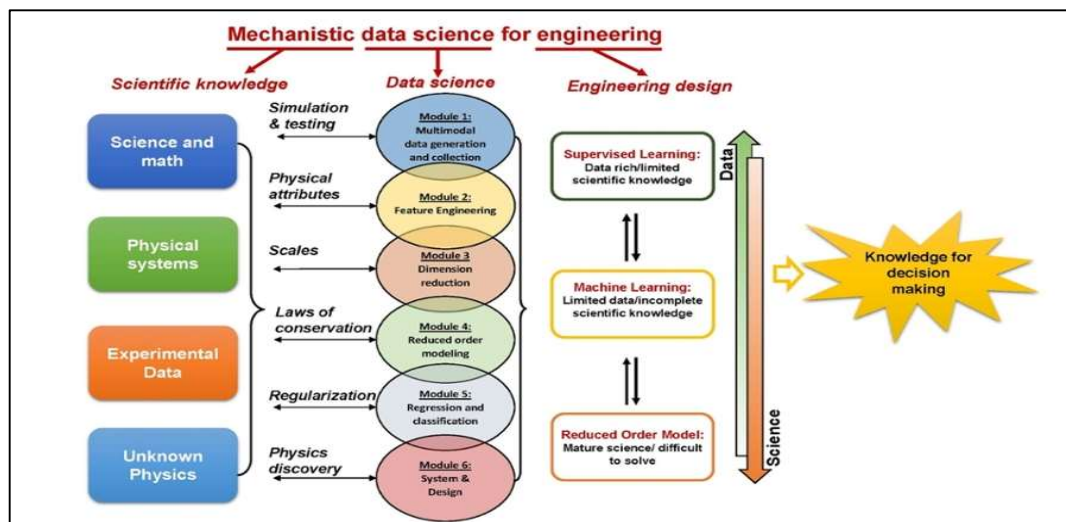
The objective of machine learning in business is not only for effective data collection, but to make use of the ever-increasing amounts being gathered by manipulating and analyzing it without heavy human input.

Machine intelligence enables complex and larger data to be processed and analyzed along with the desired results being achieved such as determining customer trends, detecting fraud, spotting buying trends and other primary objectives.

Machine learning in business therefore offers an important commercial benefit in being able to make the best use of your data.

Indeed, a key objective of machine learning is to enable you to keep up with those competitors already making best use of their data to maximize business opportunities.

Most commercial and non-commercial organizations benefit from machine learning, so it's highly likely that some form of machine intelligence can be put to use in your business.

OBJECTIVE

The purpose of machine learning is to discover patterns in your data and then make predictions based on often complex patterns to answer business questions, detect and analyses trends and help solve problems.

Machine learning in business and other fields is effectively a method of data analysis that works by automating the process of building data models.

Machine Learning brings many new and exciting approaches, especially for mechanical engineering. The efficiency, flexibility and quality of the systems can be significantly improved with the help of the available data. New business models for customers are developed. Machine Learning ensures that software and information technology are increasingly becoming the key drivers of innovation in mechanical engineering.

In many industries, the increasing interchangeability of individual machines will mean that in future not only the machine itself will be sold, but above all supplementary services. It also explains why machine learning is on the agenda in management and in many specialist areas of mechanical engineering companies.

PROJECT PLAN
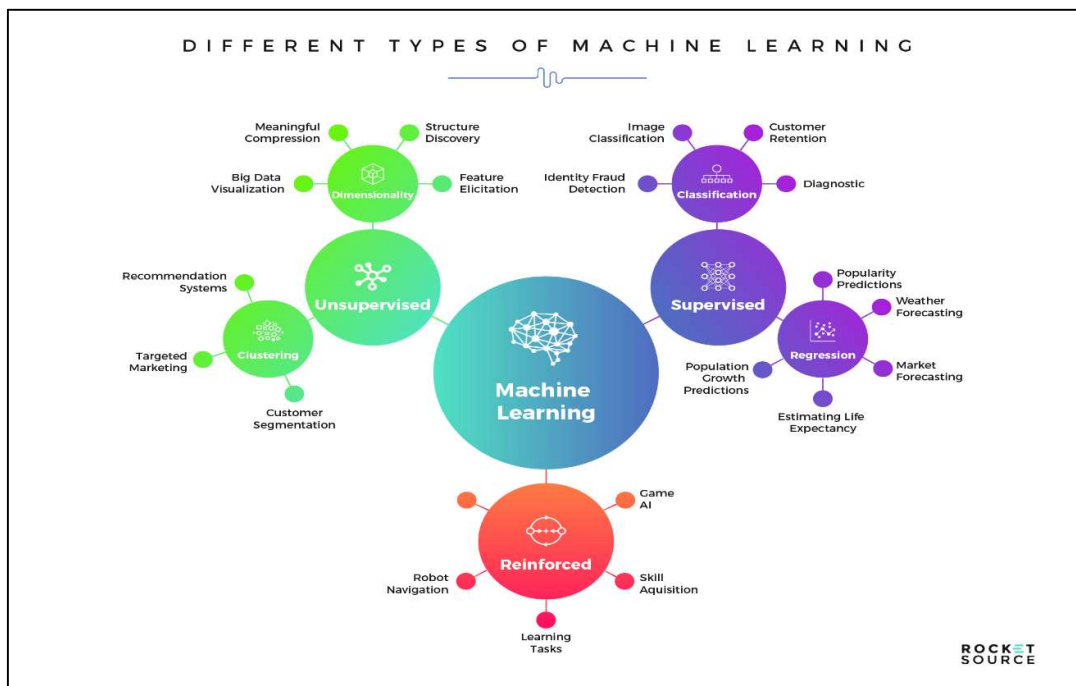
Machine Learning Components

Key components of Machine Learning, which are:

• **Data (and Its Various Types)**

The raw dataset is the foundation of Data Science, and it can be of various types like structured data (mostly in a tabular form) and unstructured data (images, videos, emails, PDF files, etc.)

• **Programming (Python and R)**

Data management and analysis is done by computer programming. In Data Science, two programming languages are most popular: Python and R.

• **Statistics and Probability**

Data is manipulated to extract information out of it. The mathematical foundation of Data Science is statistics and probability. Without having a clear knowledge of statistics and probability, there is a high possibility of misinterpreting data and reaching at incorrect conclusions. That's the reason why statistics and probability play a crucial role in Data Science.

• **Machine Learning**

As a Data Scientist, every day, you will be using Machine Learning algorithms such as regression and classification methods. It is very important for a Data Scientist to know Machine learning as a part of their job so that they can predict valuable insights from available data.

- **Types of Machine Learning**

There are three fundamental techniques of Machine learning – structured, unstructured, and reinforced learning.

1. **Structured:** Structured learning is suitable when we are aware of both – inputs and outcomes.

2. **Unstructured:** This type of learning is useful for complex problems where we don't know what the right answer is. It tries to figure out what the input is by studying the input values. This ML model requires an enormous amount of input data before devising an algorithm to solve a given problem.

3. **Reinforcement learning:** Whenever there are consequences to the inaccurate outcomes, reinforced learning is used. It penalizes the wrong outcome and rewards the correct solution. This type of machine learning is useful for designing driverless cars.

- **Quality of Prediction**

After training a machine, we need to determine its effectiveness based on the quality of the predictions it makes.

1. **Overfitting: -** When the ML model tries to predict the outputs for a given set of inputs in a very vigorous way, in other words - it is biased to the input and gives incorrect output for even a slight variation in the input value, it is known as overfitting.

2. **Underfitting: -** It is a situation when an application can neither model the training data nor generalize to new data. It is mainly due to inefficient algorithms. The only remedy to underfitting is trying alternative machine learning algorithms.

<u>Advantages of Machine Learning in Automation Industries</u>

Companies that don't realize the importance of machine learning are doing a slow and resource-consuming job, which brings them back to the middle Ages. They decrease the quality and speed of production by doing a lot of manual work and making human errors. This is what machine learning won't let you do.

1. Improved Customer Experience Personalization: -

Machine learning will help you attract more people to your product or service and turn them into regular customers. You will be able to analyze customers' browsing experience and behavior on your platform to offer them exactly what they need.

Suppose a recent search request of a user was "red sneakers", and earlier they browsed middle-priced shoes of a specific brand. Based on this data, your platform will offer them all they were looking for. It will automatically create relevant recommendations of middle-priced red sneakers of a searched brand for this particular user.

Case in point, the recommendation engine running in Netflix helped the streaming service attract a vast audience and increase profits by effectively encouraging binge-watching. As of 2018, more than 80% of Netflix viewers watched shows following the recommendations enabled with machine learning.

On the overall, by personalizing customer experience with machine learning, you'll get:

- bigger revenue due to higher customer engagement;
- increased customer satisfaction and, hence, higher brand loyalty;
- less time on research compared to the traditional methods of statistics;
- saved money on staff, office, and equipment.

2. Effective Work Processes Automation: -

Delegating manual and repetitive tasks to the machine increases the speed of production. At the same time, it helps to eliminate manual data entry errors and data duplication, ensuring the higher quality of work. Besides, you won't need a developer to reprogram the system over again every time you want to change the workflow inside the company. By learning data continuously, your platform will be able to improve its performance and adjust work processes in the company without human assistance.

Thus, by automating business processes with machine learning, you will:

- make products and/or provide services faster;
- cut expenses on software maintenance;
- save money on staff by delegating workload to machines;
- save time on finding human resources to do the job;
- make high-quality products by removing human error;
- reduce administrative tasks and paperwork, etc.

3. Powerful Predictive Ability

While some companies use the predictive powers of ML and know what they can do to improve products or services in advance, their competitors that use traditional statistical methods stay at the research stage. There are two ways you can benefit from the ML predictions:

- **Customer choice predictions.** Based on customer data, the machine learning system recognizes typical and atypical behavior patterns. With this information, you can predict the changing demands for your products, features, or services and build the most effective marketing strategies to grow sales. Moreover, by knowing people's preferences, you will understand the exact amount of time and material resources to use in production.
- **Market change forecast.** Large enterprises can get their systems programmed to process enormous market data and provide forecasts on upcoming innovations or changes. Consequently, you will be able to use trends faster than your competitors and predict business risks considering important market events.
  As a result, the ML predictions will let you:
- know trends before your competitors;
- save time and money resources for production and promotion;
- build long-term relationships with customers;
- increase customer engagement and satisfaction;
- push powerful sales strategies to make bigger profits;
- understand how to keep your business on the run within global changes.

4. Reasonable Resource Planning: -

Based on the predictions obtained via machine learning, a company can estimate the resources required to meet changing demands for its products or services. Knowing in advance what your customers expect from your company in the near future will help you in inventory and process management.
Using machine learning for resource planning will allow you to:
- save money on supplies by knowing the right amount of product to keep on hand;
- set work responsibilities wisely by understanding the exact amount of work to do;
- have enough products, even during high sales growth period;
- decrease the risk of waste materials.

5. Easy Changes within Company: -

The scope of ML benefits isn't limited to customer acquisition and marketing campaigns. You can set and manage workflow, follow staff progress, and maintain corporate values inside your company more efficiently. Any time you want to change something within your workspace, the system will be able to adopt all the changes quickly and reorganize the existent business processes.
  Thus, with a machine learning solution, your company will get:
- faster adaptation to changing work processes;
- wiser task prioritization and division between workers;
- higher transparency of work processes among employees;
- better productivity due to measuring staff behavior in the workplace;
- easier integration of new technologies into the existing system.

6. Fast Adaptation to Market Changes: -

Large enterprises like Google, Apple, or Amazon are game-changers in the global market, so many companies follow their activity to understand how they can improve their business. The ML predictions give you a competitive advantage over other companies by letting you know beforehand how large companies will influence the market and what products and services will be relevant according to their activity.

So, ML will help your business stay marketable by:

- providing insights into market movement and letting you know global trends in advance;
- ensuring the basis for efficient sales and marketing strategies in the future;
- helping you manage time, money, and human resources ahead of time;
- letting you adapt to changing business environment faster and easier.

7. Advanced Customer Support: -

The ML solutions help to improve customer relationship management because it makes chatbots and voice assistants' implementation possible. With these technologies, your own customers take an active part in service improvement, because systems learn directly from your customers when they enter text or say something to chatbots or voice assistants.

The benefits of customer support enabled with ML are:

- 24/7 available customer service from all corners of the world;
- saved time on introducing products to customers by automated FAQ answering;
- reduced cost of human labor because the initial communication is delegated to bots;
- improved customer engagement, since people tend to prefer chats over live conversations.

8. Increased Data Security: -

The security of the company and its customers has always been essential for successful business development. For instance, PayPal uses ML to ensure payment security. By noticing changes in data on financial transactions, such as sender and recipient information, credit card activity, date and time of the transaction, amount of payment, etc. the PayPal system is able to detect financial fraud.

Machine learning is used for face recognition to ensure a higher level of security. You can see this feature on Facebook when you are tagging someone in the picture or asked to authorize by the system in case it noticed suspicious activity on your profile. In medicine, ML helps hospitals keep patient's health information confidential and available for attending physicians.

Thus, by increasing the security of your data with ML, you get:

- eliminated fraudulent actions related to financial and personal data usage;
- increased customer trust by keeping their information confidential;
- reduced information leaks within the company.

9. More Productive Staff Training: -

Machine learning improves staff productivity and the quality of staff in companies. It eases the onboarding of new employees and helps your regular workers train their professional skills. For example, if your company provides consulting services, you can set an AI/ML system to simulate real conversations with clients. During the probation period at work, these systems can educate your workers and help them become more confident and competent in customer service.

Consequently, the advantages you can use at this point are:

- faster staff onboarding;
- improved competence of employees;
- saved time and money compared to human mentorship programs;
- higher quality of customer service, hence, increased customer satisfaction;
- better productivity of regular employees since they are more focused on work rather than mentoring newcomers.

10. Efficient Data Management: -

Growing volumes of data that companies collect and use each day become difficult to manage. Machine learning helps to separate relevant data from peripheral information and spam. This is how Google Gmail works. Google uses the TensorFlow ML library that, as of 2019, helped to eliminate 100 million spam messages per day, so people don't have their inbox clogged up.

So, in terms of data management, machine learning will help you to:

- save time by dividing important and peripheral work data for your employees;
- make your staff more productive since employees concentrate on higher priority tasks;
- drive higher user engagement by offering customers only relevant information, etc.

<u>Applications of Machine Learning in Automation Industries</u>

1. Next-generation optimization for manufacturers with Machine Learning

The two major use cases of Machine Learning in manufacturing are [Predictive Quality & Yield](#), and Predictive Maintenance.

<u>Predictive Maintenance</u> is the more commonly known of the two, given the significant costs maintenance issues and associated problems can incur, which is why it is now a fairly common goal amongst manufacturers.

Instead of performing maintenance according to a predetermined schedule or using SCADA systems set up with human-coded thresholds, alert rules and configurations, predictive maintenance uses algorithms to predict the next failure of a component/machine/system. Personal can then be alerted to perform focused maintenance procedures to prevent the failure, but not too early so as to waste downtime unnecessarily. By contrast, traditional manual and semi-manual approaches don't take into account the more complex dynamic behavioral patterns of the machinery, or the contextual data relating to the manufacturing process at large. For example, a sensor on a production machine may pick up a sudden rise in temperature. A static rule-based system would not take into account the fact that the machine is undergoing sterilization and would proceed to trigger a false-positive alert.

The advantages are numerous and can significantly reduce costs while eliminating the need for planned downtime in many cases.

By preempting a failure with a machine learning algorithm, systems can continue to function without unnecessary interruptions. When maintenance is needed, it's very focused – technicians are informed of the components that need inspection, repair and replacement; which tools to use, and which methods to follow.

Predictive maintenance also leads to a longer Remaining Useful Life (RUL) of machinery and equipment since secondary damage is prevented while smaller labour forces are needed to perform maintenance procedures.

<u>Predictive Quality and Yield</u> — sometimes referred to as just "Predictive Quality" — is a more advanced use case of Industrial Artificial Intelligence, that reveals the hidden causes of many of the perennial process-based production losses manufacturers face on a daily basis. Examples include quality, yield, waste, throughput, energy efficiency, emissions, and more — essentially any loss caused by process inefficiencies.

Predictive Quality and Yield automatically identifies the root causes of process-driven production losses using continuous, multivariate analysis, powered by Machine Learning algorithms that are uniquely trained to intimately understand each individual production process.

Automated recommendations and alerts can then be generated to inform production teams and process engineers of an imminent problem, and seamlessly share important knowledge on how to prevent the losses before they happen.

Reducing these types of losses has always been a struggle for manufacturers of all stripes. But in today's marketplace, this mission is more important than ever before.

On the one hand, consumers' expectations are higher than ever before; global consumer habits are gradually "westernizing", even as the population boom continues. According to numerous surveys, the global population will grow by 25% by 2050, equating to some 200,000 additional mouths to feed every day. On the other hand, consumers have never had so many alternatives available to them, in almost every product imaginable. Recent surveys indicate that this wealth of options means consumers are increasingly likely to permanently ditch even their favorite brands if, for example, a product isn't available on the shelf.

Against such a backdrop, manufacturers can no longer afford to take process inefficiencies, and their associated losses, in their stride. Every loss in terms of waste, yield, quality or throughput chips away at their bottom line and hands another inch to the competition.

The challenge for many manufacturers is that they eventually hit a glass ceiling in terms of process optimization. Some inefficiencies don't have any obvious cause, and process experts are left at a loss to explain them. That's where Machine Learning — and particularly Automated Root Cause Analysis — can really save the day.

2. Main categories of Machine Learning — and how they relate to manufacturing

Machine Learning can be split into two main techniques – Supervised and Unsupervised machine learning.

1. Supervised Machine Learning

In manufacturing use cases, supervised machine learning is the most commonly used technique since it leads to a predefined target: we have the input data; we have the output data; and we're looking to map the function that connects the two variables.

Supervised machine learning demands a high level of involvement – data input, data training, defining and choosing algorithms, data visualizations, and so on. The goal is to construct a mapping function with a level of accuracy that allows us to predict outputs when new input data is entered into the system.

Initially, the algorithm is fed from a training dataset, and by working through iterations, continues to improve its performance as it aims to reach the defined output. The learning process is completed when the algorithm reaches an acceptable level of –accuracy.

In manufacturing, there are two most common Supervised Learning approaches:

Classification and Regression

These 2 approaches share the same goal: to map a relationship between the input data (from the manufacturing process) and the output data (known possible results such as quality or waste losses, part failure, overheating etc.)

Regression

Regression is used when data exists within a range (eg. temperature, weight), which is often the case when dealing with data collected from sensors.

In manufacturing, regression can be used to calculate an estimate for the Remaining Useful Life (RUL) of an asset. This is a prediction of how many days or cycles we have before the next component/machine/system failure.

For regression, the most commonly used machine learning algorithm is Linear Regression, being fairly quick and simple to implement, with output that is easy to interpret. An example of linear regression would be a system that predicts temperature, since temperature is a continuous value with an estimate that would be simple to train.

Classification

When data exists in well-defined categories, Classification can be used. An example of Classification that we're all familiar with is the email filter algorithm that decides whether an email should be sent to our spam folder, or not. Classification is limited to a Boolean value response but can be very useful since only a small amount of data is needed to achieve a high level of accuracy.

In machine learning, common Classification algorithms include naive Bayes, logistic regression, support vector machines and Artificial Neural Networks.

2. Unsupervised Machine Learning

With Supervised machine learning we start off by working from an expected outcome and train the algorithm accordingly. Unsupervised learning is suitable for cases where the outcome is not yet known.

Clustering

In some cases, not only will the outcome be unknown to us, but information describing the data will also be lacking (data labels). By creating clusters of input data points that share certain attributes, a Machine Learning algorithm can discover underlying patterns.

Clustering can also be used to reduce noise (irrelevant parameters within the data) when dealing with extremely large numbers of variables.

Artificial Neural Networks

In the manufacturing sector, Artificial Neural Networks are proving to be an extremely effective unsupervised learning tool for a variety of applications including production process simulation and Predictive Quality Analytics.

The basic structure of the Artificial Neural Network is loosely based upon how the human brain processes information using its network of around 100 billion neurons, allowing for extremely complex and versatile problem solving.
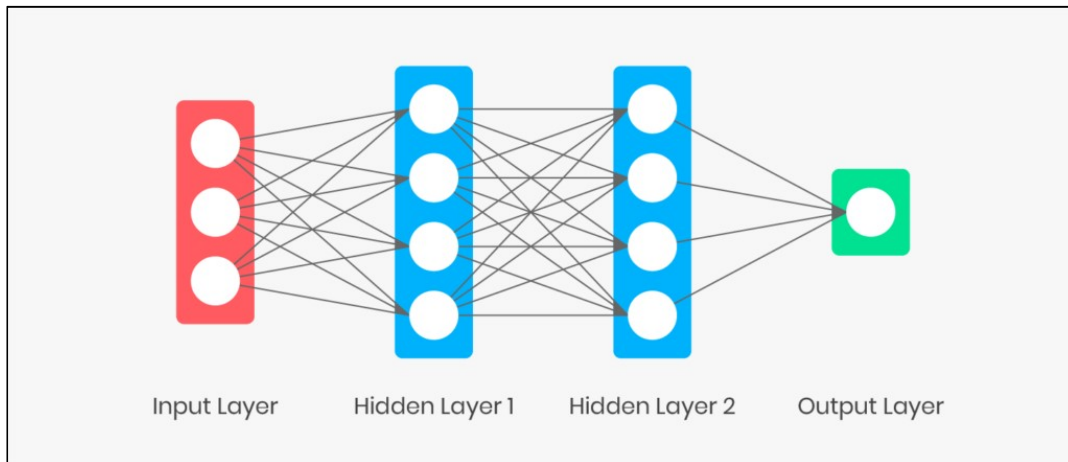
A basic schematic of a feed-forward Artificial Neural Network. Every node in one layer is connected to every node in the next. Hidden layers can be added as required, depending on the complexity of the problem.

This ability to process a large number of parameters through multiple layers makes Artificial Neural Networks very suitable for the variable-rich and constantly changing processes common to manufacturing. Moreover, once properly trained, an Artificial Neural Network can demonstrate a high level of accuracy when creating predictions regarding the mechanical properties of processed products, enabling cuts in the cost of raw materials.

Data Preparation

Machine learning is all about data, so understanding some key elements about the quality and type of data needed is extremely important in ensuring accurate results.

With Predictive Quality and Yield, for example, we're focused on process inefficiencies. Therefore, it makes sense to start by collecting historical data about the performance of the line or lines in question, as well as the losses incurred over time, in order to form predictions about future potential losses.

To get the fullest, most accurate picture possible, that data should be gathered from as many sources as possible, since manufacturing processes – especially more complex ones – are affected by a very wide range of factors that are often interdependent. This can include everything from process data, quality data, raw materials, and even external factors like weather and temperature.

Next, and just as importantly, we need to decide what question we want the Machine Learning model to answer – and whether it is possible to answer this question using the data that's available.

The Groundbreaking Benefits of Machine Learning and AI for Manufacturing

The introduction of AI and Machine Learning to industry represents a sea change with many benefits that can result in advantages well beyond efficiency improvements, opening doors to new business opportunities.

Some of the direct benefits of Machine Learning in manufacturing include:

- Reducing common, painful process-driven losses e.g. yield, waste, quality and throughput

- Increased capacity by optimizing the production process

- Enabling growth and expansion of product lines at scale due to a more optimized process

- Cost reduction through Predictive Maintenance. PdM leads to less maintenance activity, which means lower labor costs and reduced inventory and materials wastage.

- Predicting Remaining Useful Life (RUL). Knowing more about the behavior of machines and equipment leads to creating conditions that improve performance while maintaining machine health. Predicting RUL does away with "unpleasant surprises" that cause unplanned downtime.

- Improved supply chain management through efficient inventory management and a well monitored and synchronized production flow.

- Improved Quality Control with actionable insights to constantly raise product quality.

- Improved Human-Robot collaboration improving employee safety conditions and boosting overall efficiency.

- Consumer-focused manufacturing – being able to respond quickly to changes in the market demand.

CONCLUSION

This paper has presented the synopsis of our Major Project, i.e. Machine Learning. It has shown all the required information about the introduction, objective, plan, advantages and application of the project.

Machine learning offers numerous advantages to small and mid-size companies as well as large enterprises by providing them with:

- *an efficient solution for business process automation;*
- *a technology that saves a considerable amount of time, money and human resources;*
- *a helpful tool providing with customer preference insights and market forecasts;*
- *a marketing instrument for customer experience personalization;*
- *a reliable tool for monitoring transactions and detecting fraud in the Fintech industry;*
- *a utility that helps with patient diagnostics in healthcare, and more.*

Various industries appreciate this technology for predictive powers, resource-saving capabilities, and efficient customer management that allow companies to avoid as many mistakes as possible in their business.

We would like to extend our sincere gratitude to Dr. Deepak Bharadwaj for guiding us in our project. We would also like to appreciate the immense support provided by our honorable HOD Sir and other faculty members who are always there to guide us and help us in the time of need.