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PREDICTIVE MAINTENANCE OF HVAC SYSTEMS IN ZERO ENERGY BUILDINGS

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Park green energy

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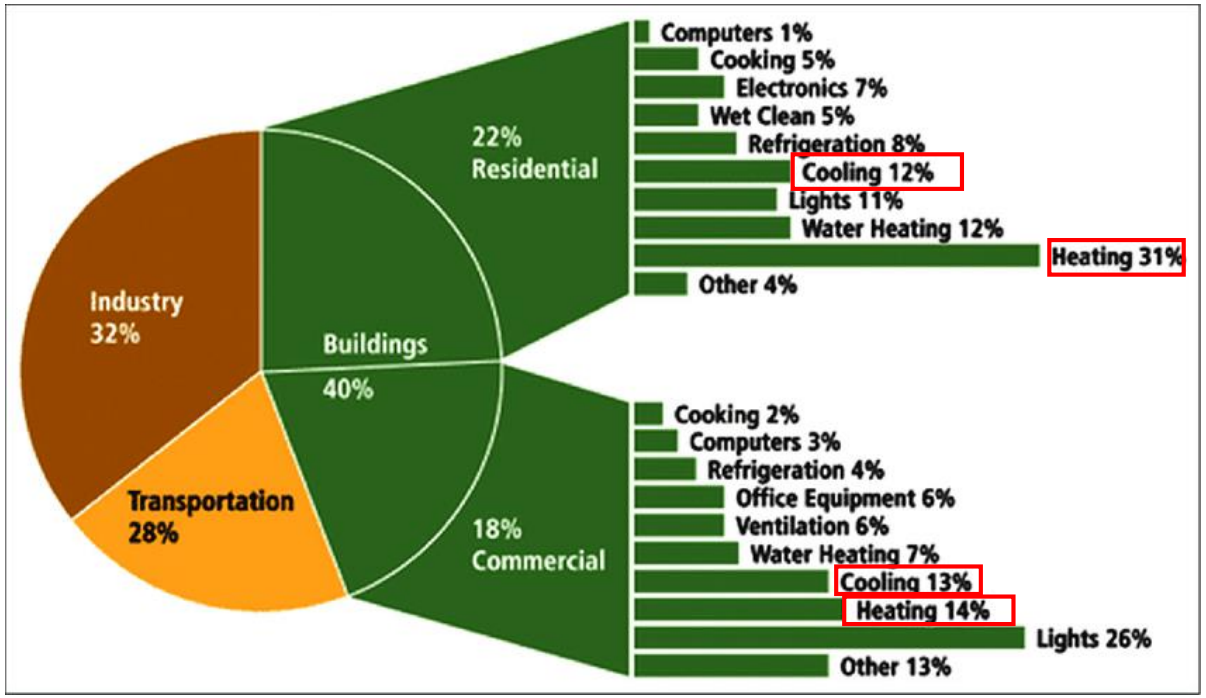
Introduction

- The building sector is considered one of the main factors affecting energy expenditure and greenhouse gas emissions, approximately 20-40% of the total energy consumption.
- The HVAC system plays a major role in the overall energy consumption of buildings and represents 30-50% of the energy used in buildings.
- Maintenance of these HVAC systems accounts for more than 65% of annual facility management costs.
- Effective maintenance strategies can reduce building maintenance costs and even extend the life of building components.
- It is then important to plan maintenance actions before a failure occurs, and not too late. But also, not too early. Since the costs of maintenance and support can account for 60 – 75% of the total lifecycle costs of a manufacturing system.



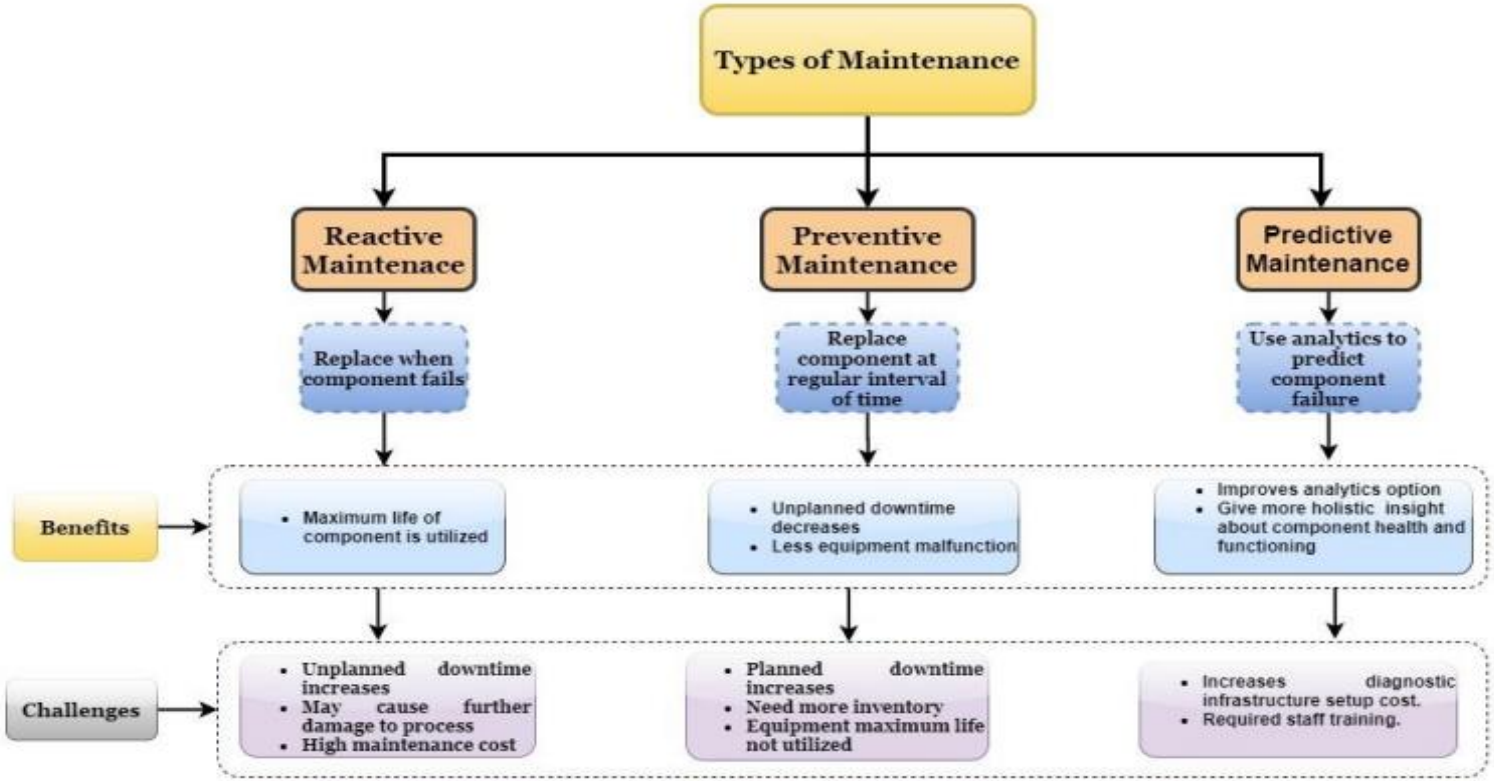
Energy consumption by sectors

Ahmadi-Karvigh, S., Ghahramani, A., Becerik-Gerber, B., & Soibelman, L. (2018). Real-time activity recognition for energy efficiency in buildings. Applied energy, 211, 146-160.

Introduction

- In reactive maintenance, the maintenance of the equipment is done once the equipment is down or starts malfunctioning. Reactive maintenance provides maximum utilization of that equipment or part, but at the same time, **it leads to unplanned downtime of the machine due to the sudden malfunctioning of the component**. Malfunctioning of the component may potentially damage the machine or process, which also causes high maintenance costs.

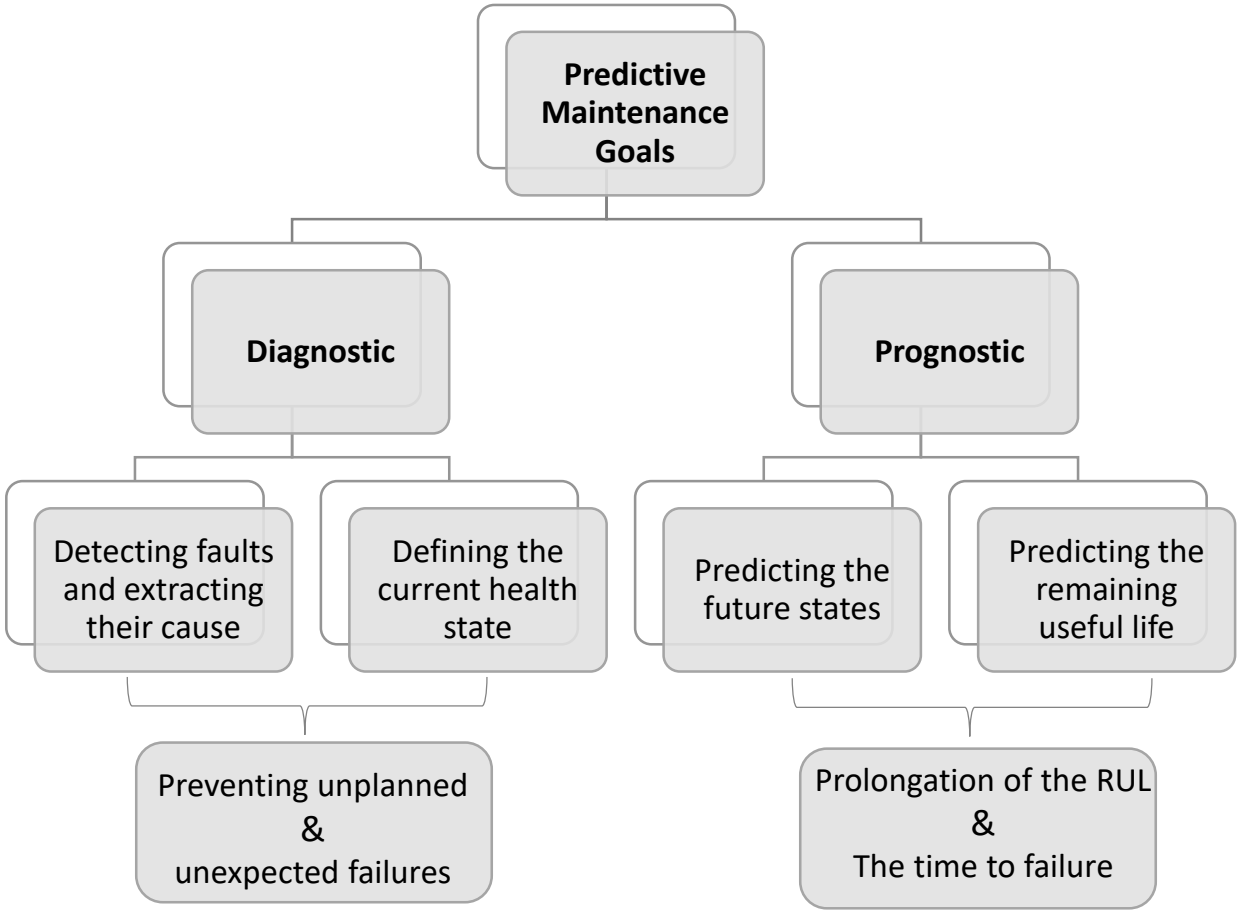
- In preventive maintenance, maintenance is done on an equal interval basis. The component is replaced after an equal interval of time to avoid further damage. Due to this preventive maintenance strategy, the overall malfunction of machines or equipment is reduced, but at the same time**, it increases the planned downtime of the machine.**



Types of maintenance strategies along with their benefits and challenges

Predictive Maintenance

- Predictive maintenance helps to detect the failure of equipment before it occurs and to know exactly when it is going to happen and which part of the system is going to be affected. This intelligent sort of maintenance leads to an enormous reduction in operation and maintenance costs of the whole system. Furthermore, it reduces the time and energy of maintenance stuff since they are going to work just when it is necessary and at the exact time needed, not too early and not too late.
- The time to failure (TTF) prediction serves to determine the amount of time equipment is meant to last in its operation mode.
- Predictive maintenance is generally applied by adopting systems that collect data from sensors and actuators to establish diagnostics and prognostics analysis.

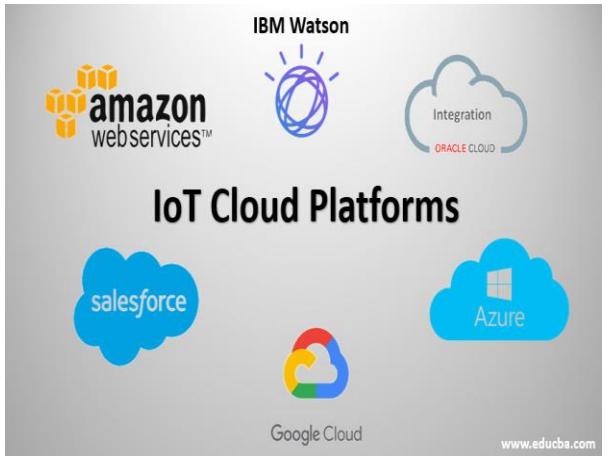


Eventual goals of predictive maintenance

Predictive Maintenance Tools

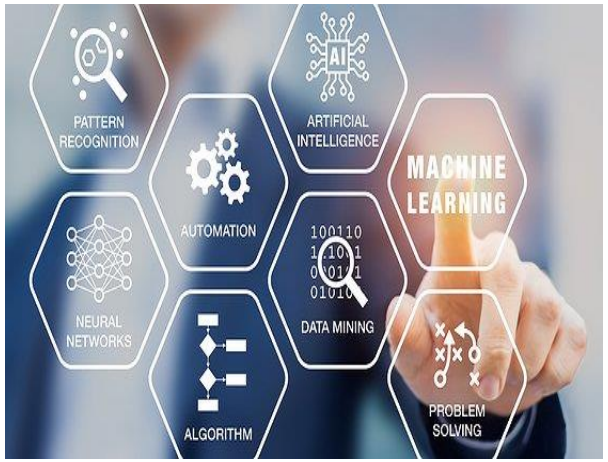
IoT Sensors

- Vibration
- Pressure
- Temperature
- Signal



IoT Platformes

- Google Cloud IoT
- IBM Watson IoT
- AWS IoT
- Microsoft Azure IoT



Algorithmes

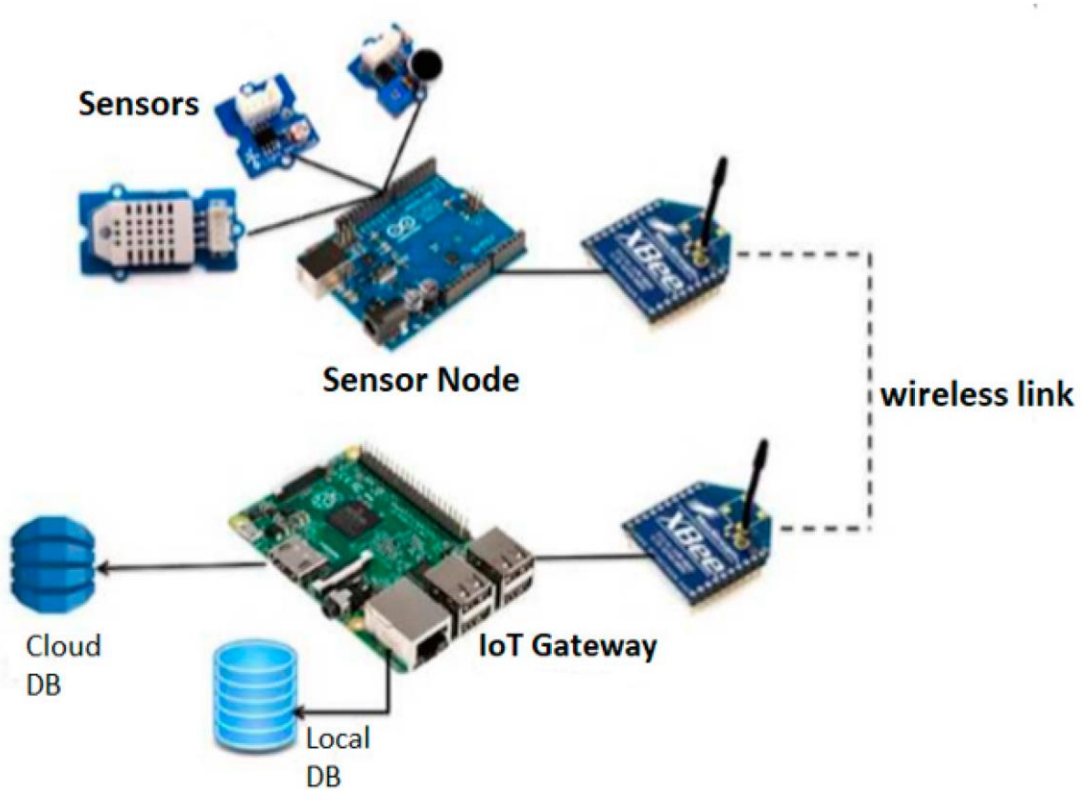
- Machine Learning
- Deep Learning

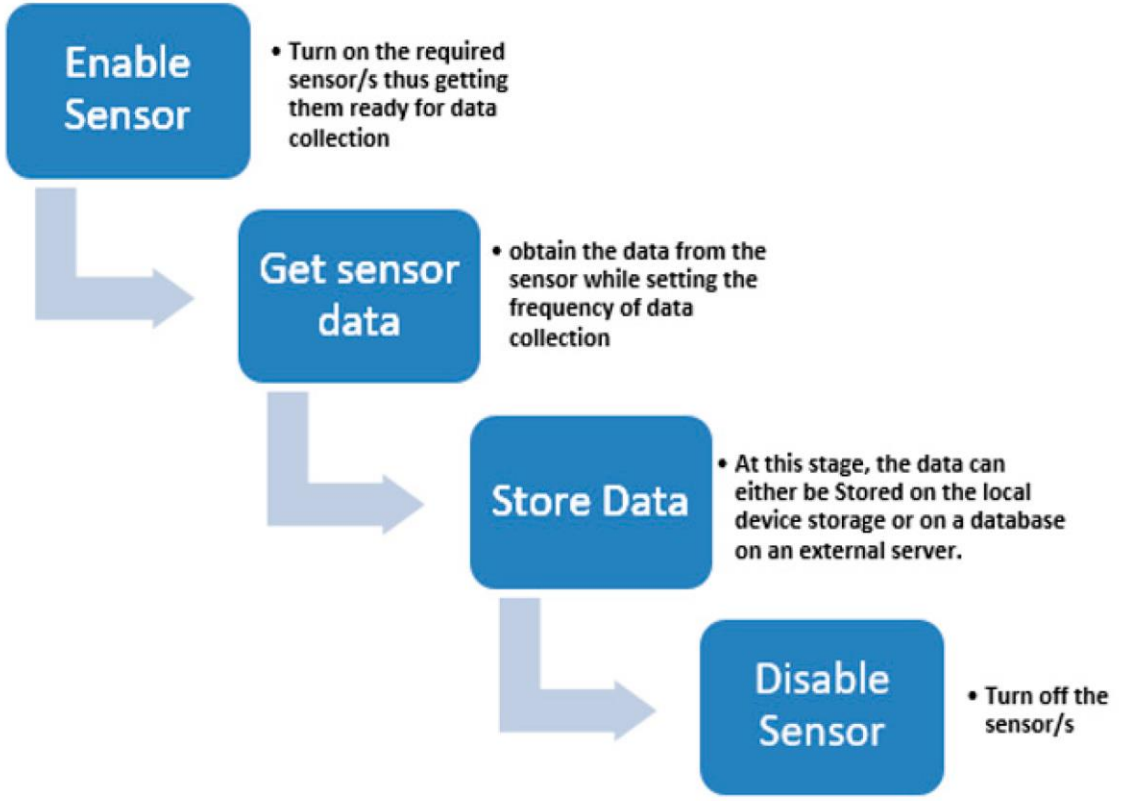
Application

Predictive Maintenance Tools

IoT Sensors

The Internet of Things, also called IoT, is a way for a user to get information and data on a device by connecting it. To retrieve this information it is necessary to choose the most suitable communication protocol for these connected objects.





Predictive Maintenance Tools

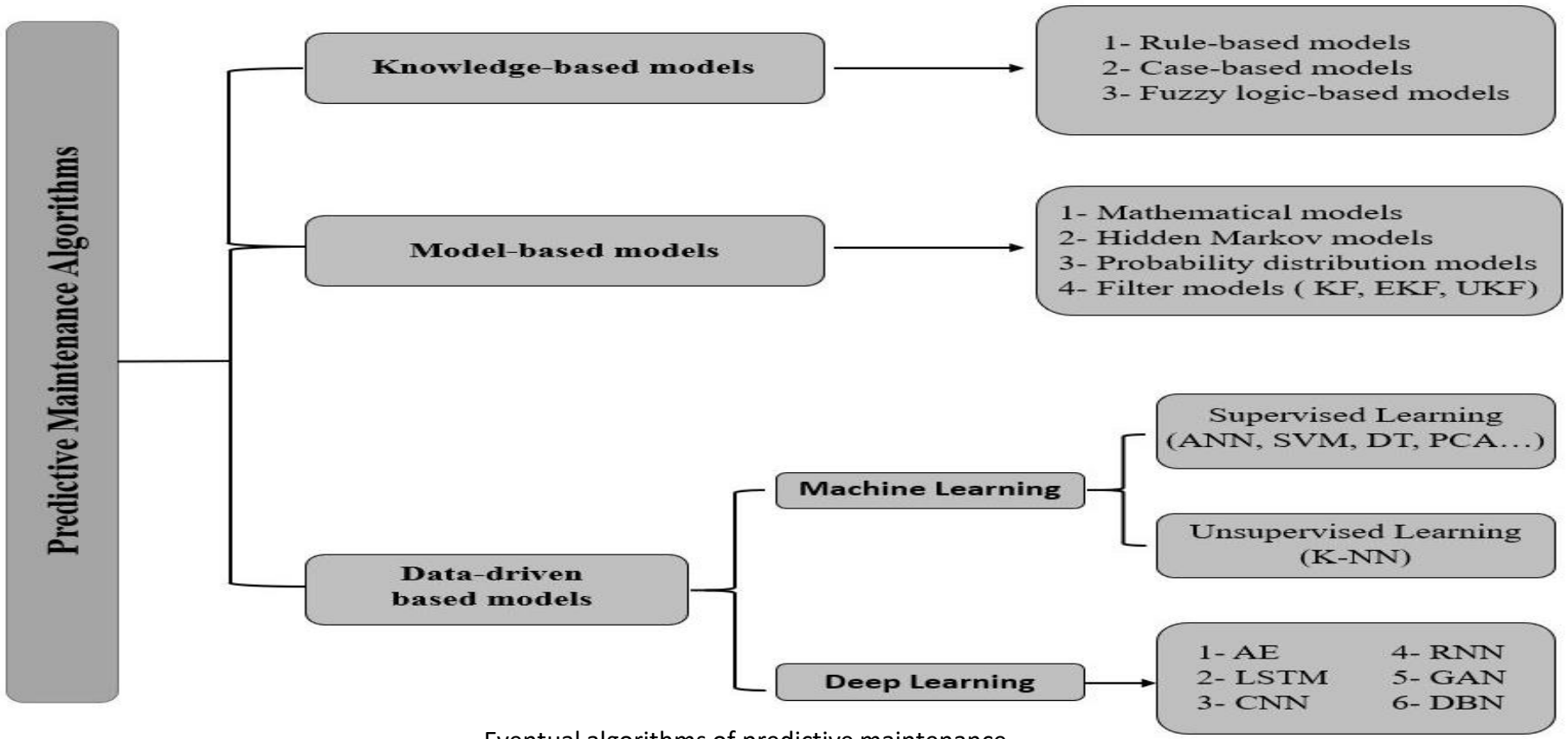
IoT Platformes

The IoT platform brings together a set of services that enable data collection, storage, correlation, analysis, and exploitation. It thus refers to the supporting software that connects the entire IoT system, facilitating communication, data flow, device management, and application functionality. The platform connects devices to a cloud through flexible connectivity options.

Predictive Maintenance Tools

PdM Algorithms

To apply predictive maintenance, there are several approaches to take into account; either knowledge-based approaches or physical-based model approaches, or even data-driven approaches.



Eventual algorithms of predictive maintenance

Data driven-based models

- In data-driven models, data is collected from the sensors installed in the equipment, components, and machines for fault prediction. The collected data features are extracted for processing, analysis, and degradation of information included in the data.
- To apply this model, the proper machine learning or deep learning algorithm should be selected according to the corresponding parameters of the equipment.
- ML is a subcategory of AI and it can be defined as an algorithm that can learn with the smallest support possible.
- ML-based models have enormous advantages since they can deal with multivariate, high-dimensional data and have the ability to extract hidden relationships between data in any environment.

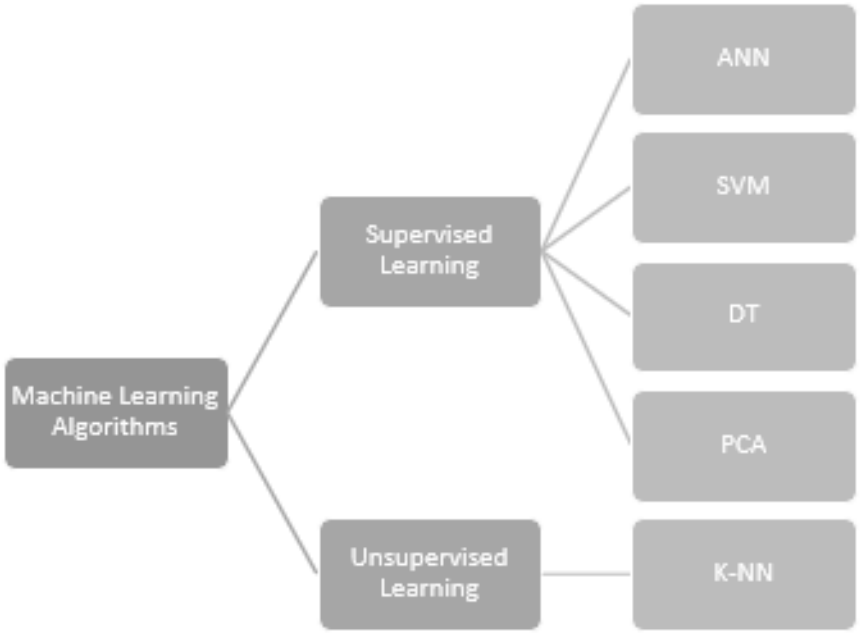


Figure 5. Classification of Machine Learning algorithms

Conclusion

- The task of predictive maintenance by estimating and predicting the RUL is still challenging due to the complex, uncertain, nonlinear features and operational conditions. The main challenges can be summarized in several aspects such as;

1. The lack of input data because most data-driven models, especially machine learning approaches, predict the RUL based on the extracted data.

2. Even though classification algorithms have shown excellent accuracy in distinguishing states, they need to be trained with a complete dataset of all failures

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3. The algorithms are selected based on the developer's experience and this may influence the variability of the prediction results.

- SVM and ANN, are the most widely used ML algorithms in the literature. They have been successfully applied in several areas of predictive maintenance applications.

- Conducting a study with only one prediction method may not show excellent results. Therefore, applying other methods to provide comprehensive results by applying the hybrid and multi-based models is recommended.

- So, according to the conducted survey, it can be recommended to combine more than one single ML or DL model in order to provide a better prediction compared to using an individual model. Thus, classification and anomaly detection algorithms are also suggested to be combined in order to maintain the accuracy of classification models without losing the benefits of anomaly detection algorithms. In this way, predictive maintenance can be applied to different HVAC systems that do not have a large data set.

Thank you for your attention

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