ML 4 Predictive Maintenance: Challenges and Countermeasures

Thank you for joining our survey! You're invited to take part in our voluntary research study.

This survey explores the application of Machine Learning, Deep Learning, Transfer Learning, and Reinforcement Learning algorithms for predictive maintenance purposes in real industrial contexts. The main focus is on the identification of relevant challenges that limit the adoption of ML for predictive maintenance and potential countermeasures.

Completing this anonymous online survey will take approximately 15 minutes, and your responses will remain confidential, with no individual data shared. There are no known risks associated with participation. You can stop participation at any time without providing a reason. The data from the survey will be used to develop academic publications.

We appreciate your contribution to this research.

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* Indicates a mandatory question

1. I certify that I am 18 years old or older *

   Mark only one oval.

   - ◯ Yes
   - ◯ No

2. I have read and understood the information provided, and I voluntarily consent to participate in the survey *

   Mark only one oval.

   - ◯ Yes
   - ◯ No

Machine Learning and Deep Learning typical challenges

The adoption of Machine Learning, Deep Learning, Transfer Learning, and Reinforcement Learning for predictive or condition-based maintenance is limited by several challenges. In this context, to what extent you consider the following challenges relevant? Please, provide also potential countermeasures for each challenge.

From here on, we will only refer to Machine Learning, Deep Learning, Transfer Learning, and Reinforcement Learning simply as Machine Learning.

3. Evaluate the relevance of the challenge "**Data Heterogeneity**" as described below: *

The adoption of Machine Learning is hindered by data coming from several sources (e.g., sensors, IoT devices etc…), which may be characterized by different formats, structures, quality level, sampling rates, time stamps, etc..

Mark only one oval.

- ◯ Not relevant
- ◯ Slightly relevant
- ◯ Moderately relevant
- ◯ Very relevant
- ◯ Extremely relevant

4. With reference to the previous challenge ("**Data Heterogeneity**"), please indicate potential countermeasures. *

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5. Evaluate the relevance of the challenge "**Data Scarcity**" as described below: *

An effective training phase of Machine Learning requires a large amount of **FAILURE** data, which are often difficult to acquire in practical applications.

Mark only one oval.

- ◯ Not relevant
- ◯ Slightly relevant
- ◯ Moderately relevant
- ◯ Very relevant
- ◯ Extremely relevant

6. With reference to the previous challenge ("**Data Scarcity**"), please indicate potential countermeasures. *

7. Evaluate the relevance of the challenge "**Data Storage**" as described below: *

High requirements in terms of storage capacity are needed to store the data required by Machine Learning.

Mark only one oval.

- ◯ Not relevant
- ◯ Slightly relevant
- ◯ Moderately relevant
- ◯ Very relevant
- ◯ Extremely relevant

8. With reference to the previous challenge ("**Data Storage**"), please indicate potential countermeasures. *

9. Evaluate the relevance of the challenge "**Training Complexity**" as described below: *

There is a high risk of overfitting when training a Machine Learning model.

Mark only one oval.

- ◯ Not relevant
- ◯ Slightly relevant
- ◯ Moderately relevant
- ◯ Very relevant
- ◯ Extremely relevant

10. With reference to the previous challenge ("**Training Complexity**"), please indicate potential countermeasures. *

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11. Evaluate the relevance of the challenge "**Machine Learning model selection**" as described below: *

The selection of an appropriate Machine Learning algorithm is challenging due to the several available Machine Learning models.

Mark only one oval.

- ◯ Not relevant
- ◯ Slightly relevant
- ◯ Moderately relevant
- ◯ Very relevant
- ◯ Extremely relevant

12. With reference to the previous challenge ("**Machine Learning model selection**"), please indicate potential countermeasures. *

13. Evaluate the relevance of the challenge "**Computational Complexity**" as described below: *

Training a Machine Learning model requires a massive amount of data. Consequently, this results in extensive consumption of high-performance computing resources and long training times

Mark only one oval.

- ◯ Not relevant
- ◯ Slightly relevant
- ◯ Moderately relevant
- ◯ Very relevant
- ◯ Extremely relevant

14. With reference to the previous challenge ("**Computational Complexity**"), please indicate potential countermeasures. *

15. Evaluate the relevance of the challenge "**Feature Selection**" as described below: *

Selecting the most relevant features is necessary to avoid the problems generated by data excess, but it is not an easy task since it relies heavily on labor and requires extensive domain knowledge.

Mark only one oval.

- ◯ Not relevant
- ◯ Slightly relevant
- ◯ Moderately relevant
- ◯ Very relevant
- ◯ Extremely relevant

16. With reference to the previous challenge ("**Feature Selection**"), please indicate potential countermeasures. *

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17. Evaluate the relevance of the challenge "**Data Privacy**" as described below: *

The use of Machine Learning is accompanied by issues related to data breaches and cyber-attacks.

Mark only one oval.

- ◯ Not relevant
- ◯ Slightly relevant
- ◯ Moderately relevant
- ◯ Very relevant
- ◯ Extremely relevant

18. With reference to the previous challenge ("**Data Privacy**"), please indicate potential countermeasures. *

19. Evaluate the relevance of the challenge "**Infrastructure Selection**" as described below: *

It is difficult to decide the best infrastructure for the intended application due to the variety and heterogeneity of available software and hardware.

Mark only one oval.

- Not relevant
- Slightly relevant
- Moderately relevant
- Very relevant
- Extremely relevant

20. With reference to the previous challenge ("**Infrastructure Selection**"), please indicate potential countermeasures. *

21. Evaluate the relevance of the challenge "**High Infrastructure Cost**" as described below: *

High infrastructure-related investments are required to have an appropriate network and storage capabilities for Machine Learning.

Mark only one oval.

- ◯ Not relevant
- ◯ Slightly relevant
- ◯ Moderately relevant
- ◯ Very relevant
- ◯ Extremely relevant

22. With reference to the previous challenge ("**High Infrastructure Cost**"), please indicate potential countermeasures. *

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23. Evaluate the relevance of the challenge "**Low Quality/Noisy Data**" as described below: *

The acquired data are affected by noise

Mark only one oval.

- ◯ Not relevant
- ◯ Slightly relevant
- ◯ Moderately relevant
- ◯ Very relevant
- ◯ Extremely relevant

24. With reference to the previous challenge ("**Low Quality/Noisy Data**"), please indicate potential countermeasures. *

25. Evaluate the relevance of the challenge "**One model for one machine**" as described below: *

Poor generalization ability of developed models: many developed models show poor performance when applyed to different types or even the same type of equipment under different operational environments.

Mark only one oval.

- ◯ Not relevant
- ◯ Slightly relevant
- ◯ Moderately relevant
- ◯ Very relevant
- ◯ Extremely relevant

26. With reference to the previous challenge ("**One model for one machine**"), please indicate potential countermeasures. *

27. Evaluate the relevance of the challenge "**Machine Learning Model Interpretability**" as described below: *

Features used by Machine Learning models are difficult to understand and interpreted physically; consequently, industry experts do not trust the models.

Mark only one oval.

- Not relevant
- Slightly relevant
- Moderately relevant
- Very relevant
- Extremely relevant

28. With reference to the previous challenge ("**Machine Learning Model Interpretability**"), please indicate potential countermeasures. *

29. Evaluate the relevance of the challenge "**Machine Learning Result Interpretability**" as described below: *

The decisions of Machine Learning models lack explainability and interpretability.

Mark only one oval.

- Not relevant
- Slightly relevant
- Moderately relevant
- Very relevant
- Extremely relevant

30. With reference to the previous challenge ("**Machine Learning Result Interpretability**"), please indicate potential countermeasures. *

31. Evaluate the relevance of the challenge "**Sensor Selection**" as described below: *

There are a lot of types of sensors and it is hard to decide which type to adopt based on the requirements in terms of reliability, accuracy etc..

Mark only one oval.

- Not relevant
- Slightly relevant
- Moderately relevant
- Very relevant
- Extremely relevant

32. With reference to the previous challenge ("**Sensor Selection**"), please indicate potential countermeasures. *

33. Evaluate the relevance of the challenge "**Specialized Workforce**" as described below: *

The implementation of Machine Learning algorithms for predictive maintenance requires specialized workforce with knowledge of Machine Learning

Contrassegna solo un ovale.

- ◯ Not relevant
- ◯ Slightly relevant
- ◯ Moderately relevant
- ◯ Very relevant
- ◯ Extremely relevant

34. With reference to the previous challenge ("**Specialized Workforce**"), please indicate potential countermeasures. *

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35. Evaluate the relevance of the challenge "**Workforce Resistance**" as described below: *

Maintenance operators are reluctant to adopt Machine Learning algorithms for carrying out maintenance activities and to be trained for it

Contrassegna solo un ovale.

- ◯ Not relevant
- ◯ Slightly relevant
- ◯ Moderately relevant
- ◯ Very relevant
- ◯ Extremely relevant

36. With reference to the previous challenge ("**Workforce Resistance**"), please indicate potential countermeasures. *

37. Evaluate the relevance of the challenge "**Managerial Support**" as described below: *

Managers are reluctant to adopt Machine Learning algorithms for carrying out maintenance activities

Contrassegna solo un ovale.

- Not relevant
- Slightly relevant
- Moderately relevant
- Very relevant
- Extremely relevant

38. With reference to the previous challenge ("**Managerial Support**"), please indicate potential countermeasures. *

39. Evaluate the relevance of the challenge "**Machine Update**" as described below: *

New machines are required and/or old machines need to be adapted to support the installation of sensors to collect the required data

Contrassegna solo un ovale.

- Not relevant
- Slightly relevant
- Moderately relevant
- Very relevant
- Extremely relevant

40. With reference to the previous challenge ("**Machine Update**"), please indicate potential countermeasures. *

41. Evaluate the relevance of the challenge "**Trust in Machine Learning**" as described below: *

There is little knowledge on which are the performance achievable by implementing Machine Learning algorithms, both in terms of operational performance (e.g., accuracy, generalizability, ...) and economic performance (e.g. ROI, maintenance costs reduction, …), which results in low trust in Machine Learning

Contrassegna solo un ovale.

- Not relevant
- Slightly relevant
- Moderately relevant
- Very relevant
- Extremely relevant

42. With reference to the previous challenge ("**Trust in Machine Learning**"), please indicate potential countermeasures. *

43. Evaluate the relevance of the challenge "**Dynamic Market**" as described below: *

The market is changing very quickly and Machine Learning models need to be adapted and modified every time a change occurs

Contrassegna solo un ovale.

- Not relevant
- Slightly relevant
- Moderately relevant
- Very relevant
- Extremely relevant

44. With reference to the previous challenge ("**Dynamic Market**"), please indicate potential countermeasures. *

45. Evaluate the relevance of the challenge "**Certification**" as described below: *

Installation and application of a Machine Learning maintenance program needs to be certified

Contrassegna solo un ovale.

- ◯ Not relevant
- ◯ Slightly relevant
- ◯ Moderately relevant
- ◯ Very relevant
- ◯ Extremely relevant

46. With reference to the previous challenge ("**Certification**"), please indicate potential countermeasures. *

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47. Evaluate the relevance of the challenge "**Workforce Training**" as described below: *

Training for learning and using Machine Learning is expensive and time-consuming

Contrassegna solo un ovale.

- ◯ Not relevant
- ◯ Slightly relevant
- ◯ Moderately relevant
- ◯ Very relevant
- ◯ Extremely relevant

48. With reference to the previous challenge ("**Workforce Training**"), please indicate potential countermeasures. *

49. Evaluate the relevance of the challenge "**Accuracy Issue**" as described below: *

Machine Learning algorithms are characterized by low accuracy

Contrassegna solo un ovale.

- ◯ Not relevant
- ◯ Slightly relevant
- ◯ Moderately relevant
- ◯ Very relevant
- ◯ Extremely relevant

50. With reference to the previous challenge ("**Accuracy Issue**"), please indicate potential countermeasures. *

51. If there was something unclear or that could have been better specified, please mention it and provide specific suggestions