Project Group:
Machine Learning for Predictive Maintenance
(Weekly Status Report)

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Calendar Week: 7 19 February, 2021

Completed Tasks

1. Updated the health state classification chapter with second review comments of Paul.

Tasks in-progress

1. Working with interface team i.e. Christopher, Sanjay and Gourav for creating class diagrams for the system design milestone.

2. Checking with Saghar on the contents for UML diagrams specific to health state classification chapter.

Calendar Week: 6 11 February, 2021

Completed Tasks

1. Updated the alpha version of health state classification chapter with comments given by Selami and Sanjay.

2. Reviewed the feature extraction chapter and prepared a feedback for that chapter.

Tasks in-progress

1. Need to update the health state classification chapter with second review comments of Paul and Gourav.

Calendar Week: 5 5 February, 2021

Completed Tasks

1. Reviewed the health index estimation chapter and prepared a feedback for that chapter.

Tasks in-progress

1. Working on review comments of the health state classification chapter given by Selami and Sanjay.

Calendar Week: 04 29 January, 2021

Completed Tasks

1. Finalized with the alpha version of health state estimation chapter.
2. Prepared minutes for weekly status meeting on 27 January 2021.

Tasks in-progress

1. Preparing the review for health index chapter.

Calendar Week: 03 21 January, 2021

Completed Tasks

1. Updated the approaches such as DBN and logistic regression associated with health state estimation.
2. Updated the evaluation metrics dealing with the classification models.
3. Updated the introduction to health state chapter.

Tasks in-progress

1. Finalizing the health state chapter for review.

Calendar Week: 02 15 January, 2021

Completed Tasks

1. Updated the formal definition of health state estimation as per review comments of Tanja.
2. Updated the dataset part of survey report with regard to chapter health state estimation by removing the GHL dataset.
3. Modified preliminary versions of state of the art approaches namely SVM.

Tasks in-progress

1. To add on further details to approaches ANN and CART associated with supervised health state classification.
2. To build the contents for evaluation for approaches involved.

Calendar Week: 01 10 January, 2021

Completed Tasks

1. Discussed with Saghar on the data sets to be added in the survey report for health state estimation.

2. Prepared preliminary versions of state of the art approaches namely ANN, SVM and CART.

Tasks in-progress

1. To dive deeper into the concepts of different approaches (SVM , ANN and CART) associated with supervised health state classification.

2. To build the contents for evaluation for approaches involved.

References

[1] Hack-Eun Kim, Andy C.C. Tan, Joseph Mathew and Byeong-Keun Choi, "Bearing fault prognosis based on health state probability estimation", *Expert system with application 39, 2012*, https://www.sciencedirect.com/science/article/pii/S0957417411015491.

[2] Hack-Eun Kim, "Machine prognosis based on health state probability estimation", https://core.ac.uk/download/pdf/10903836.pdf.

Calendar Week: 52 - 53 30 December, 2020

Completed Tasks

1. Discussed with Saghar on the corrections of formal definition as mentioned by Tanja and updated the same in the survey report.

2. Had meeting with team member Saghar to discuss on the list of data sets for health state classification and found the following dataset-

   - Condition monitoring of hydraulic systems [1]
   - Bearing Dataset from NASA
   - Bearing Fault dataset [2]

Tasks in-progress

1. Getting more insights on different approaches (SVM , ANN and CART) associated with supervised health state classification.

2. To build the contents for data sets and various approaches involved.

References

[1] Nikolai Helwig, Eliseo Pignanelli, and Andreas Schutze, "Condition monitoring of a complex hydraulic system using multivariate statistics", *2015 IEEE International Instrumentation and MeasurementTechnology Conference (I2MTC) Proceeding*, https://doi.org/10.1109/I2MTC.2015.7151267.1.

[2] Eric Bechhoefer, "A quick introduction to bearing envelope analysis", *Green Power Monitoring Systems* https://www.mfpt.org/wordpress1/wp-content/uploads/2017/11/mfpt-bearing-envelope-analysis-1.pdf.

Calendar Week: 51 18 December, 2020

Completed Tasks

1. Discussed with team on the formal definition of time series as per [1] and updated the same in the topic-study survey report.
2. Had meeting with team member Saghar to discuss on pipeline structure health state classification section in topic survey.
3. Discussed with Saghar on the plan for second milestone to prepare plan-chart.
4. Discussed with Saghar and created formal definition of health state estimation.

Tasks in-progress

1. Getting deep understanding of various health state estimation approaches to prepare the data-sets involved in the survey report.
2. Working with team member Saghar on tasks such as list of data-sets and state-of-the-art approaches associated with health state classification to be added for the topic-study survey report.

References

[1] Tornede, Tanja and Tornede, Alexander and Wever, Marcel and Mohr, Felix and Hüllermeier, Eyke, "AutoML for Predictive Maintenance: One Tool to RUL them all", *IoTStream ECMLPKDD 2020*, 2020.

Calendar Week: 50 11 December, 2020

Completed Tasks

1. Discussed with team on the contents of introduction of topic-study survey report.
2. Had meeting with team member Saghar to discuss on sub-sections and its assignee for health state classification section in topic survey.
3. Got an understanding of paper[2].The survey mentioned the following-
   - Usage of Hidden Markov Models (HMM) in determining unobservant health states from the observable sensor data.
   - Lead of Hierarchical HMM (HHMM) over HMM in representing multiple health states along with their state transition properties.
   - Detailed description of HMM and HMMM in the area of diagnosis and prognosis of machinery parts such as drill-bits.

Tasks in-progress

1. Getting more insights from the seed literature[2] and [3] for getting more insights into topic of health state classification.
2. To state formal definition of time series.
3. Working with team member Saghar on tasks such as deciding the formal definition, pipeline elements associated with health state classification to be added for the topic-study survey report.

References

[1] O. Geramifard, J.-X. Xu, C. K. Pang, J.H. Zhou, X. Li, "Data-Driven Approaches in Health Condition Monitoring – A Comparative Study", *2010 8th IEEE International Conference on Control and Automation*, https://ieeexplore.ieee.org/stamp/stamp.jsp?tp= & arnumber=5524339.

[2] Camci, Fatih, and Ratna Babu Chinnam, "Health-state estimation and prognostics in machining processes", *IEEE Transactions on automation science and engineering* 7.3 (2010): 581-597, https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5393023.

[3] Kim, Hack-Eun, et al., "Bearing fault prognosis based on health state probability estimation.", Expert Systems with Applications 39.5 (2012): 5200-5213. 13, no. 3, https://www.sciencedirect.com/science/article/pii/S0957417411015491.

Calendar Week: 49 4 December, 2020

Completed Tasks

1. Discussed with team on the final template of topic-study survey report.
2. Acquired brief knowledge on basic steps in health state classification from dissertation [1]. The survey mentioned the following -
    - Prognostics and health management (PHM) being combination of diagnostics (fault prediction, isolation and identification), prognostics (dealing with estimation the time to failure) and decision module (predicting remaining useful time) associated with condition monitoring.
    - Fault diagnosis is linked to feature extraction as its gets its input from feature extraction module and it provides model describing current health state for prognosis (health index estimation) and decision modules.
    - Diagnostic methods are mainly classified as model-based and data-driven.
    - Model driven methods are based on calculation of residue which is deviation of at least one determining property from its acceptable behavior.
    - Data driven fault prediction mainly involves use of pattern recognition that could be done through supervised or unsupervised learning approaches.

Tasks in-progress

1. Getting more insights from the seed literature[2] and [3] provided as part of second milestone for deep diving into topic of health state classification.
2. Decide upon subsections of health state classification report and its assignee.

References

[1] J. K. Kimotho, "Development and performance evaluation of prognostic approaches for technical systems", *Ph.D. dissertation*, 2016, https://digital.ub.uni-paderborn.de/hsx/content/titleinfo/2219021.

[2] Camci, Fatih, and Ratna Babu Chinnam, "Health-state estimation and prognostics in machining processes", *IEEE Transactions on automation science and engineering* 7.3 (2010): 581-597, https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5393023.

[3] Kim, Hack-Eun, et al., "Bearing fault prognosis based on health state probability estimation.", Expert Systems with Applications 39.5 (2012): 5200-5213. 13, no. 3, https://www.sciencedirect.com/science/article/pii/S0957417411015491.

Calendar Week: 48 27 November, 2020

Completed Tasks

1. Finished with understanding of Survey paper 2[1]. The survey mentioned the following -
    - The three predictive maintenance(PdM) prognosis methods namely model-based, knowledge-based and data-driven wherein data-driven techniques lead over other two maintenance strategies.
    - Comparison between machine learning and deep learning models. Data-driven machine learning models have sub-processes such as feature extraction which is avoided by deep learning models through addition of complex layers between the input raw data and required prediction result.
    - Predictive maintenance being significant component of prognostic and health management of industrial equipment.
    - Operational assessment determining the success rate of predictive maintenance approaches.
    - Potential improvements in the field of predictive maintenance including data validity, unbalanced nature of dataset, model migration and generalization ability, unsupervised learning and safety parameters.

Tasks in-progress

1. Collecting more information on recent fault prediction techniques in the area of predictive maintenance.

References

[1] W. Zhang and D. Yang and H. Wang, "Data-Driven Methods for Predictive Maintenance of Industrial Equipment: A Survey", *IEEE Systems Journal*, vol. 13, no. 3, pp. 2213-2227, 2019, https://ieeexplore.ieee.org/document/8707108.

Calendar Week: 47 19 November, 2020

Completed Tasks

1. Completed going through of Survey paper 1 [1]. The survey described the following -
    - Lead of predictive maintenance(PdM) over reactive and preventive maintenance strategies through utilisation of latest evolving technologies such as internet of things(for data acquisition), big data(for data pre-processing), advanced deep learning(for fault diagnosis and prognosis) and deep reinforcement learning(for decision making).
    - Different types of architectures associated with predictive maintenance such as Open System Architecture for Condition based monitoring, cloud based PdM system and PdM 4.0.
    - Objectives of PdM include getting rid of abrupt downtime and making system more reliable, reduce maintenance costs involved and fix contradicting multi-objective decision scenarios.
    - Major categories of approaches involved in PdM - knowledge based, traditional machine learning(ML) based and deep learning(DL) based, of which DL based approaches apparently found to be efficient that the other two approaches.
    - Challenges faced by PdM such as complexity, higher level of automation and constantly changing nature of current industrial systems.

Tasks in-progress

1. Collecting information from second survey paper[2] which mainly explains major applications of PdM in different industrial scenarios.

References

[1] Y. Ran, X. Zhou, P. Lin, Y. Wen, and R. Deng, "A survey of predictive maintenance: Systems, purposes and approaches", *arXiv preprint arXiv:1912.07383*, 2019, https://arxiv.org/pdf/1912.07383.pdf.

[2] W. Zhang and D. Yang and H. Wang, "Data-Driven Methods for Predictive Maintenance of Industrial Equipment: A Survey", *IEEE Systems Journal*, vol. 13, no. 3, pp. 2213-2227, 2019, https://ieeexplore.ieee.org/document/8707108.

Calendar Week: 46 13 November, 2020

Completed Tasks

1. Created minutes for meeting conducted on 11 November 2020.
2. Completed understanding of Survey paper 3 [2]. The survey described following points -
   - Increasing significance of predictive maintenance in the industrial domain among different types of maintenance strategies.
   - Dominating nature of artificial intelligence approaches (machine learning techniques) for maintenance over statistical and model-based approaches.
   - Dependency of the performance of predictive maintenance over type of machine learning models used.
   - Various machine learning models involved, their merits and demerits and different types of data sets for predictive maintenance.

Tasks in-progress

1. Reading through first survey paper[1]. Going through introduction gave information on different architectures,objectives and methodologies involved in the area of predictive maintenance via machine learning techniques.

References

[1] Y. Ran, X. Zhou, P. Lin, Y. Wen, and R. Deng, "A survey of predictive maintenance: Systems, purposes and approaches", *arXiv preprint arXiv:1912.07383*, 2019, https://arxiv.org/pdf/1912.07383.pdf.

[2] T. P. Carvalho and F. Soares and R. Vita and R. Francisco and João P. Basto and Symone G.S. Alcalá, "A systematic literature review of machine learning methods applied to predictive maintenance", *Computers & Industrial Engineering*, vol. 137, p. 106024, 2019.

Calendar Week: 45 06 November, 2020

Completed Tasks

1. Connected with team for tasks such as template creation for weekly status report and JIRA setup and learned about initial set up process.

2. Went through document shared by Tanja on Introduction to predictive maintenance wherein there is brief overview on various types of maintenance strategies involved, the reason behind lead of predictive maintenance over others and major steps, targets and data involved in predictive maintenance .

Challenges

1. Creating weekly status report on Latex took more time than expected time.

Tasks in-progress

1. Collecting insights from third survey paper [1] Initial reading gave the importance of predictive maintenance in the industrial field by means of systematic analysis of data from various sources through machine learning techniques.

References

[1] T. P. Carvalho and F. Soares and R. Vita and R. Francisco and João P. Basto and Symone G.S. Alcalá, "A systematic literature review of machine learning methods applied to predictive maintenance", *Computers & Industrial Engineering*, vol. 137, p. 106024, 2019.