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

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Calendar Week: 7 19 February, 2021

Completed Tasks

1. Finished 2nd review of Health Index chapter and prepared a feedback for that chapter.
2. implemented final changes for health state classification chapter based on the 2nd review :
   - Checking the document for spelling mistakes.
   - Explaining and adding more details for unclear parts.
   - Using subsubsection and paragraph instead of textbf.
3. Had a discussion with Paul, Selami and Vinay about the date format and created a first draft for that.

Tasks in-progress

1. Working with team members to design the data format and write it in latex.
2. Working with Anurose on the contents of UML diagrams for Health State Classification chapter.

Calendar Week: 6 12 February, 2021

Completed Tasks

1. Changed the health state classification chapter based on comments given by @Selami and @Sanjay and updated the alpha version.

Tasks in-progress

1. Reading the Health Index chapter and preparing a feedback for that chapter.

2. Updating the health state classification chapter based on second review of @Paul and @Gourav.

Calendar Week: 5 5 February, 2021

Completed Tasks

1. Reviewed the feature extraction chapter and prepared a feedback for that chapter(added comments).

Tasks in-progress

1. Working on some parts of the health state classification chapter based on comments given by @Selami and @Sanjay.

Calendar Week: 4 29 January, 2021

Completed Tasks

1. Prepared a feedback for some parts like introduction, motivation,conclusion.

Tasks in-progress

1. Reading the feature extraction chapter and review it.

Calendar Week: 3 22 January, 2021

Completed Tasks

1. Wrote evaluation section of health state classification chapter.
2. Updated the motivation section of health state classification chapter by adding pipeline.
3. Updated and correcting the content of chapters.

Calendar Week: 2 15 January, 2021

Completed Tasks

1. Completing the remaining part of state of the art approaches(Fuzzy and HMM) and writing knn approach.

2. Adding images for each approach to get better understanding.

Tasks in-progress

1. Writing the content of evaluation section of health state classification chapter.

2. Writing the motivation section of health state classification .

Calendar Week: 1 8 January, 2021

Completed Tasks

1. wrote the content of dataset,namely,Condition monitoring of hydraulic systems Data Set [1]and Bearing Fault Dataset.

2. wrote first draft of state of art approaches (Fuzzy and HMM).

Tasks in-progress

1. Writing remaining state of art approach and completing it.

References

[1] Nikolai Helwig, Eliseo Pignanelli, and Andreas Schütze. "Condition monitoring of a complex hydraulic system using multivariate statistics". In: *2015 IEEE International Instrumentation and Measurement Technology Conference (I2MTC) Proceedings, Pisa, Italy, May 11-14, 2015*. IEEE, 2015, pp. 210–215. DOI: 10.1109/I2MTC.2015.7151267. URL: https://doi.org/10.1109/I2MTC.2015.7151267.

Calendar Week: 52-53 30 December, 2020

Completed Tasks

1. Working with Anurose to find related Datasets,namely, Condition monitoring of hydraulic systems Data Set [1]and Bearing Fault Dataset , Bearing Data Set from NASA.

2. Finding papers related to state of art approaches (KNN, Neuro-Fuzzy) of health state classification and understanding most important part of each methods.

3. Discussed with Anurose for correcting Formal definition of health state classification.

Challenges

1. Finding related data-sets were difficult and took more time. Most of available data set address fault detection problem(binary target classes, faulty/healthy).For instance, CNC Mill Tool Wear dataset, Air pressure system failures in Scania trucks dataset.

Tasks in-progress

1. Searching more state-of-the-art approaches papers. (HMMs, KNN, Neuro-Fuzzy).

2. Writing the content of dataset part.

References

[1] Nikolai Helwig, Eliseo Pignanelli, and Andreas Schütze. "Condition monitoring of a complex hydraulic system using multivariate statistics". In: *2015 IEEE International Instrumentation and Measurement Technology Conference (I2MTC) Proceedings, Pisa, Italy, May 11-14, 2015*. IEEE, 2015, pp. 210–215. DOI: 10.1109/I2MTC.2015.7151267. URL: https://doi.org/10.1109/I2MTC.2015.7151267.

Calendar Week: 51 18 December, 2020

Completed Tasks

1. Writing Introduction of the Topic study.
2. Discussed with Anurose and created pipeline structure for health state classification.
3. Discussed with Anurose about formal definition of health state classification and with other team members for Formal definition of time series.
4. Discussed with Anurose about work plan for the second milestone.

Challenges

1. Creating formal definition and pipeline structure took more time.

Tasks in-progress

1. Understanding of Data-driven approaches in health condition monitoring to find the related data sets.
2. Working with Anurose on list of data-sets and state-of-the-art approaches.

Calendar Week: 50 11 December, 2020

Completed Tasks

1. Created minutes for Wednesday's meeting (9 December 2020)
2. Finished reading survey "Health-State Estimation and Prognostics in Machining Processes" [1] which is focused on two approaches (regular HMM and hierarchical HMM) for health-state and calculating remaining- useful-life (RUL) estimation using Monte Carlo simulation. These approaches are implemented using example of Drill bits.
3. Assigning sections and subsections with Anurose.

Tasks in-progress

1. Searching and reading much more papers such as Reading survey "Bearing fault prognosis based on health state probability estimation" [2] and "Data-driven approaches in health condition monitoring - A comparative"[3] and so on.
2. Working on motivation content of health state classification
3. Working on Introduction of main Document of PG.
4. Joined with Anurose to creat formal definition of health state classification.

References

[1] Fatih Camci and Ratna Babu Chinnam. "Health-State Estimation and Prognostics in Machining Processes". In: *IEEE Trans Autom. Sci. Eng.* 7.3 (2010), pp. 581–597. DOI: 10.1109/TASE.2009.2038170. URL: https://doi.org/10.1109/TASE.2009.2038170.

[2] Hack-Eun Kim et al. "Bearing fault prognosis based on health state probability estimation". In: *Expert Syst. Appl.* 39.5 (2012), pp. 5200–5213. DOI: 10.1016/j.eswa.2011.11.019. URL: https://doi.org/10.1016/j.eswa.2011.11.019.

[3] Omid Geramifard et al. "Data-driven approaches in health condition monitoring - A comparative study". In: *8th IEEE International Conference on Control and Automation, ICCA 2010, Xiamen, China, June 9-11, 2010*. IEEE, 2010, pp. 1618–1622. DOI: 10.1109/ICCA.2010.5524339. URL: https://doi.org/10.1109/ICCA.2010.5524339.

Calendar Week: 49 04 December, 2020

Completed Tasks

1. Discussing and working with team members on tasks such as the report template for topic studies and decide on structures for document.

2. Reading the dissertation "Development and performance evaluation of prognostic approaches for technical systems"[1] which discussed the following points as follows:

   - Presenting prognostics and health management (PHM) as a maintenance strategy for detecting faults and predicting RUL and describing essential elements of it.
   - Giving an overview of fault diagnostic methods which identify fault type and location as a main cause of unusual system behavior with two types model-based and data-driven.
   - Explaining classification of Data-driven approaches for PHM in Statistical approach and Machine learning approach, in which pattern recognition based on supervised and unsupervised ML methods is used for detecting faults and their applications are discussed.
   - Giving an overview of fault prognostic methods which is focused on estimating the remaining useful lifetime (RUL) of a system namely, Reliability based methods using failure times of similar units, Model-driven approach employing mathematical models of system, and Data-driven approach utilizing condition monitoring data to learn degradation behavior of a system and the evaluation of each method.
   - Introducing prognostics approaches depending on the type of condition monitoring data available such as health state estimation with help of ML algorithms (SVM, RF, PNN), estimating RUL and so on.

Tasks in-progress

1. Working on the seed literature [2] and [3] to get familiar with the topic of health state classification.

2. Deciding (jointly with team member Anurose) about elements of pipeline, formal definition, sections and subsections of health state classification.

References

[1] James Kuria Kimotho. "Development and performance evaluation of prognostic approaches for technical systems". PhD thesis. University of Paderborn, Germany, 2016. URL: https://nbn-resolving.org/urn:nbn:de:hbz:466:2-27129.

[2] Fatih Camci and Ratna Babu Chinnam. "Health-State Estimation and Prognostics in Machining Processes". In: *IEEE Trans Autom. Sci. Eng.* 7.3 (2010), pp. 581–597. DOI: 10.1109/TASE.2009.2038170. URL: https://doi.org/10.1109/TASE.2009.2038170.

[3] Hack-Eun Kim et al. "Bearing fault prognosis based on health state probability estimation". In: *Expert Syst. Appl.* 39.5 (2012), pp. 5200–5213. DOI: 10.1016/j.eswa.2011.11.019. URL: https://doi.org/10.1016/j.eswa.2011.11.019.

Calendar Week: 48 27 November, 2020

Completed Tasks

1. Finished reading Survey "Data-Driven Methods for Predictive Maintenance of Industrial Equipment" [1]. In this paper, following topics are discussed:

   - Reviewing maintenance methods in which PdM leads to more promising results.
   - Explaining PdM approaches,namely, Knowledge-based prognosis, model-based prognosis and data driven prognosis where for smart manufacturing and industrial equipment, Data-Driven Models show a better performance in terms of maintenance cost reduction and reducing equipment downtime.
   - Implementation of Data-Driven PdM system in four stages(operational assessment, data acquisition, feature engineering and modeling) and proposing the PdM system using the example of automatic washing equipment and its challenges.
   - Introducing six ML and DL algorithms and their evaluation based on five proposed metrics of signal type, application scenario, target, accuracy, and data sets, among which accuracy was discussed in detail as the most important metric.

Tasks in-progress

1. Reading the dissertation "Development and performance evaluation of prognostic approaches for technical systems" [2].

References

[1] Weiting Zhang, Dong Yang, and Hongchao Wang. "Data-Driven Methods for Predictive Maintenance of Industrial Equipment: A Survey". In: *IEEE Syst. J.* 13.3 (2019), pp. 2213–2227. DOI: 10.1109/JSYST.2019.2905565. URL: https://doi.org/10.1109/JSYST.2019.2905565.

[2] James Kuria Kimotho. "Development and performance evaluation of prognostic approaches for technical systems". PhD thesis. University of Paderborn, Germany, 2016. URL: https://nbn-resolving.org/urn:nbn:de:hbz:466:2-27129.

Calendar Week: 47 20 November, 2020

Completed Tasks

1. Finished reading first Survey [1] which is focused on three types of maintenance strategies and their differences. It also introduces Technologies and system architectures and the Ways through which they contribute to PdM.

    - In final part, it gives an overview of DL based Methods for fault diagnosis and prognosis in PdM, namely, Auto encoder, CNN, RNN and so on.

      The survey also describes the features,advantages, disadvantages and different applications for each DL-based approach to select best DL method for particular PdM applications.

Challenges

1. Understanding complex structures of some DL based approaches.

Tasks in-progress

1. Reading survey "Data-Driven Methods for Predictive Maintenance of Industrial Equipment" [2]

References

[1] Yongyi Ran et al. "A Survey of Predictive Maintenance: Systems, Purposes and Approaches". In: *CoRR* abs/1912.07383 (2019). arXiv: 1912.07383. URL: http://arxiv.org/abs/1912.07383.

[2] Weiting Zhang, Dong Yang, and Hongchao Wang. "Data-Driven Methods for Predictive Maintenance of Industrial Equipment: A Survey". In: *IEEE Syst. J.* 13.3 (2019), pp. 2213–2227. DOI: 10.1109/JSYST.2019.2905565. URL: https://doi.org/10.1109/JSYST.2019.2905565.

Calendar Week: 46 13 November, 2020

Completed Tasks

1. Finished reading Survey 3 [1]. which its highlighted points are as follows:
    - Systematic literature review to recognize and categorize relevant literature to PdM using ML methods.
    - The most used ML methods for PdM in Literature, namely, Random Forest , ANN, SVM, K-Mean (which are referred as Traditional ML based approaches in Survey 1).

Challenges

1. Some Parts of Survey 1 were complicated and for a better understanding of basic concepts, I started with reading Survey 3.

Tasks in-progress

1. Reading the remaining part of first Survey : DL based Approaches [2].

References

[1] Thyago Peres Carvalho et al. "A systematic literature review of machine learning methods applied to predictive maintenance". In: *Comput. Ind. Eng.* 137 (2019). DOI: 10.1016/j.cie.2019.106024. URL: https://doi.org/10.1016/j.cie.2019.106024.

[2] Yongyi Ran et al. "A Survey of Predictive Maintenance: Systems, Purposes and Approaches". In: *CoRR* abs/1912.07383 (2019). arXiv: 1912.07383. URL: http://arxiv.org/abs/1912.07383.

Calendar Week: 45 06 November, 2020

Completed Tasks

1. Joined and followed Christopher and Paul by setting up JIRA and GitLab and getting familiar with the process and platforms.
2. Designed Weekly Report Template in Word and converted in Latex format (completed and uploaded by Sanjay).

Challenges

1. Getting familiar with basic concepts in PdM.

Tasks in-progress

1. Reading relevant literature (First Survey)[1].
    - Existing system architectures of PdM and their structures and standards(OSA-CBM,Cloud-Enhanced PdM systems,Pdm 4.0).
    - Organizing the possible approaches in PdM (knowledge based, traditional ML based,DL based approaches).
    - Think about advantages and disadvantages of knowledge based approach.

References

[1] Yongyi Ran et al. "A Survey of Predictive Maintenance: Systems, Purposes and Approaches". In: *CoRR* abs/1912.07383 (2019). arXiv: 1912.07383. URL: http://arxiv.org/abs/1912.07383.