Layerwise Relevance Propagation applied to BERT Model tested on Text dataset for predictive maintenance of Green Hydrogen Infrastructure

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Abstract: This paper encompasses the implementation of hydrogen text dataset to verify the BERT model with LRP algorithm. The layer-wise relevance propagation is adapted for the better understanding of the model parameters .The complete algorithm was first applied to the UCI SECOM dataset and verified the results. Next , applied on datasets Hydrogen Incident and Accident Database, National Renewable Energy Laboratory ,U.S. Department of Energy. LRP with epsilon rule was applied to the BERT model .LRP was applied on the classifier layer using CLS embeddings from BERT to obtain interpretable relevance scores .Results are verified for two epochs showing remarkable score with respect to High prediction accuracy ,Good fault classification capability, and effective predictive maintenance model.

Keywords: BERT model ,classification, NLP datasets ,LRP, compatibility check of both the algorithms

Introduction

Various techniques are observed on the concept of predictive maintenance .Predictive maintenance has been incorporated as an important area of interest for Green hydrogen manufacturers in recent years, as it permits for the proactive identification and knowledge of equipment issues before they are of serious nature . Through the implementation of various algorithms such as random forests, gradient boosting, and deep learning, machine learning can be adopted for better prediction of failures.

This research work proposes a predictive maintenance system for green hydrogen system, designed to detect potential equipment malfunctions before they result in significant operational failures.Natural language models and Explainable AI models based on Bidirectional Encoder Representations from Transformers(BERT) and layer-wise relevance propagation are proposed here for the text classification and proper interpretation and understanding of the model.One block diagram is proposed for justifying the idea of interpretability and trust-worthy model by using layerwise relevance propagation.

Related work

The paper suggests any damage before it occurs. It also informs about the working of PDM, the significance of sensors, and the tools that is considered as the base of PdM.[1]It highlights the issues of PdM, like usage of quality data, and the importance of skilled workers.The process will encompass its influence to various sectors related to Power,medicine , conveyance,and, the dependability of crucial systems in these area can be guaranteed.

Grey, blue, and green hydrogen are the primary hydrogen production methods which are compared with respect to the hydrogen electrolysis process, and different electrolyzer technologies are included.[2].Hydrogen can be the ingredient in fuel cells to generate power using a chemical reaction instead of combustion, producing only water and heat as byproducts. There are many applications for example in day today life based on green hydrogen,because Hydrogen has low energy density and It can be available with the help of compression and liquefaction, no matter it is costly. Hydrogen in liquid form needs almost one-third of its

heating value . Transporting fluid hydrocarbon fuels is more cheaper than hydrogen distribution [3].Because of hydrogen dimensions, it is more prone to leakage, which should be avoided as far as storage and transportation are concerned. The proposed PdM algorithm permits a very interesting decision rule which is taken care for maintenance management, and relevant for big and critical data issues.[4].Multiple classification modules with different prediction horizons are provided to achieve different performance tradeoffs with respect to occurrences of sudden breaks and unexploited lifetime, and forwarding the same to a maintenance decision system to reduce cost to a certain extent.

Knowing the text of log messages in the dashboard, upcoming failure can be understood beforehand. The unstructured log messages are cleaned and grouped into structured form which can be extracted significantly [5].The recommendation from data insight can be fed to text preparation for recognizing with maintenance details. The maintenance normally utilize the output from sensors which are temperature or vibration and these can be linked to the degradation process of the system. Further , sensor data are not so easily utilized for the next step , so event logs generated by the machine are used instead . To recognize patterns which are preceded a failure incident an event-based method with registered events are developed.The paper suggests a remarkable algorithm with text classificationon the cyber-physical infrastructure of an Industry. The aim is to enhance the accuracy of prediction with the given industrial figures.[6]The author deliberates to manage the production processes of manufacturing industries efficiently. The algorithms display execution time which is not affected by the dimension, and seamless manipulation without facing any other computational costs.

The detection of anomalies can be experienced by using the supervised machine learning technique like feed-forward neural network.[7]It is advisable to use a supervised learning algorithm when there are samples with common range.Isolation Forest also works well in high dimensional problems which have a large number of irrelevant attributes, and in situations where training set does not contain any anomalies.[8].Methods for machine learning interpretability can be classified according to various criteria.[9]Without machine learning there can be no interpretable machine learning. Therefore we have to guess where machine learning is heading before we can talk about interpretability.

Decisions now will decide which countries and companies lead and profit from the new hydrogen age[10].Figure 1 and 2 indicate different techniques and leakage issues in Green Hydrogen Infrastructure.

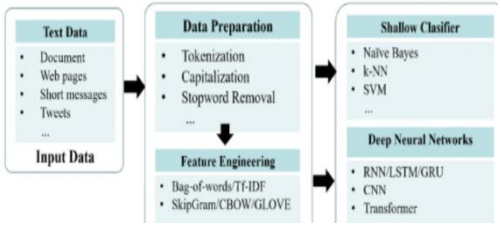


Fig.1 Different techniques studied

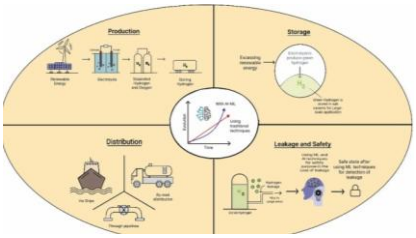


Fig.2 Leakage and safety of Green Hydrogen Infrastructure

Work Done with algorithm:

The paper proposes a new method which combines BERT model for text classification with explainable AI concept layerwise relevance propogation.The dataset in this paper is taken from IEEE repositories. The complete algorithm was first applied to the UCI SECOM dataset and

verified the results. Next ,applied on datasets Hydrogen Incident and Accident Database,National Renewable Energy Laboratory ,U.S. Department of Energy.The dataset is in the form of text which needs pre-processing .The next step is to apply BERT model to seggregate different peaks which indicate the faults as follows:-

Experimental work and Datasets:

A few faults are indicated over here.

A few data is indicated here to show the kind of text information in Green Hydrogen Infrastructure

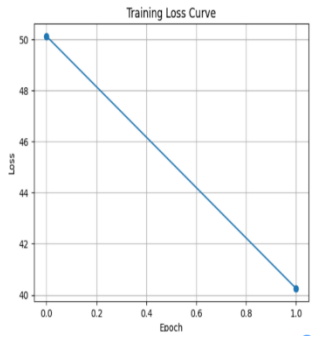
ID	Incident Title	Cause	Leak Type	Pressure Context	Location	Description	Keywords	Severity
1	Pipeline Rupture	Equipment Failure	Sudden	High	Industrial Plant	Valve failure under high pressure in pipeline system	valve, rupture, pressure	High
2	Storage Tank Leak	Corrosion	Gradual	Medium	Storage Facility	Small hydrogen leak detected due to corrosion	tank, corrosion	Medium
3	Compressor Failure	Equipment Failure	Sudden	High	Refinery	Leak caused by compressor seal damage	compressor, seal	High
4	Valve Mis-operation	Human Error	Sudden	High	Industrial Plant	Leak caused by incorrect valve operation	valve, human error	High
5	Pipe Crack	Material Fatigue	Gradual	Medium	Pipeline	Slow leakage due to fatigue crack formation	crack, fatigue	Medium

Results and Discussion: BERT classification report

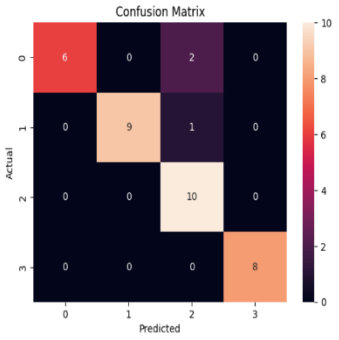
Class	Precision	Recall	F1-Score	Support
Technical	1.00	0.75	0.86	8
Material	1.00	0.90	0.95	10
Human	0.77	1.00	0.87	10
Other	1.00	1.00	1.00	8
Accuracy	-	-	0.92	36
Macro Avg	0.94	0.91	0.92	36

Class	Precision	Recall	F1-Score	Support
Weighted Avg	0.94	0.92	0.92	36

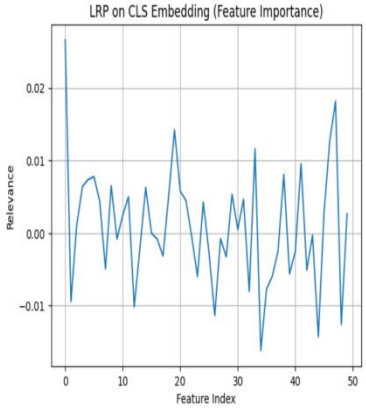
2. Training loss curve

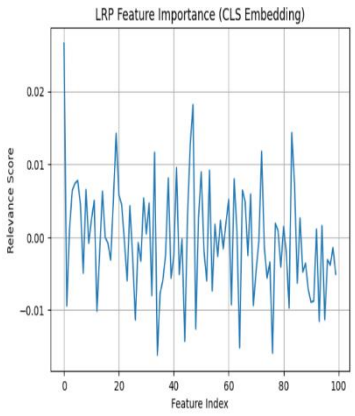


3.Confusion Matrix



4. Feature classification - one and two





Conclusion:

Different methods were studied related to classification and trustworthy explainable AI .

Supervised Learning Methods like Support Vector Machines (SVM): Effective for binary classification of failure/no-failure based on extracted features , Random Forests (RF): Robust to overfitting, performs well on tabular maintenance data ,Artificial Neural Networks (ANN): Capable of learning complex mappings between features and target failure labels,Unsupervised Learning Methods ,Principal Component Analysis (PCA): Used for anomaly detection and dimensionality reduction ,K-means Clustering: Detects operational states and shifts in normal behavior without labels . Deep Learning Approaches like Recurrent Neural Networks (RNN)/LSTMs: Model time-series degradation patterns for Remaining Useful Life (RUL) estimation,Autoencoders: Detect anomalies by reconstructing normal operational data . Integrated Gradient method can be clubed with bert Model but here LRP is included because it redistributes relevance scores and efficient .

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