Mooring Line and Machine Learning

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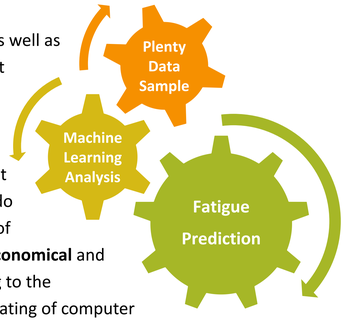
Research Poster Presentation for InnovateUNO 2019

Introduction

In the field of naval architecture especially for offshore structures, mooring lines are such an essential part that must be attached great importance to.

However now the traditional as well as the most popular way to detect mooring line integrity mostly relies on watching water circles.



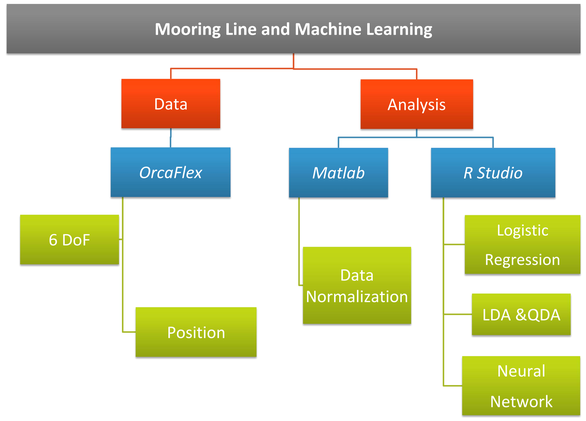
Therefore this research is about one of the latest new ways to do the prediction of the integrity of mooring lines which is more **economical** and has **higher reliability** according to the accuracy and high speed calculating of computer algorithm. The data post process method used here is machine learning which is highly efficient for data analysis since it is a big data epoch now.

Objective

- Less Cost
- More Accurate

Summary

As a further step taken based on the foundation of the previous research by *Igor Prislin* and *Soma Maroju* [1] , which concluded that metocean variables are not significant enough. Hence here the input data would ignore the environment parameters and instead, only focus on 6 DoF (6 Degrees of Freedom) and Position. And all of the data information would come from the results of the powerful industrial simulation software —— *OrcaFlex* (Version 10.3d).

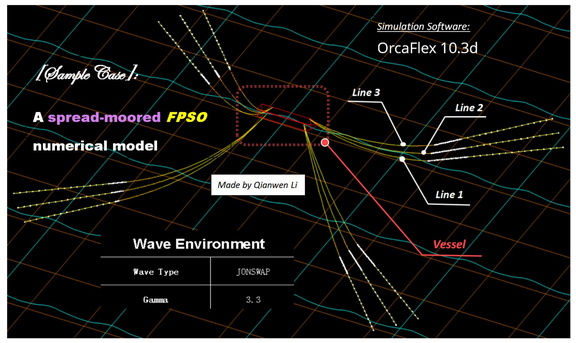


After 4 hours' simulation calculation, about 24,000 groups data obtained and *Matlab* is used here for data normalization. In order to have bigger possibility to get the correct prediction, different machine learning methods are applied and comparing their reliability by relative tables, graphs and plots. How to manage that is to deal with data by applying different models including LR, LDA, QDA and Neural Network in the Maths professional software *R studio*.

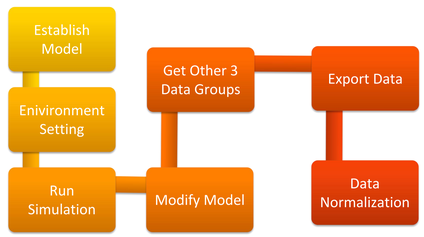
Materials & Methods

- ***Data***

The kind of offshore structures chosen as an example here is FPSO, which is one of the most useful and most commonly used in the industry. And sea state as the background would be the North Sea for it is one of the most dangerous sea state so that makes it could be the worst case for mooring lines and give the highest and most strict demands for the qualification. And therefore the North Sea still hasn't been explored enough which means abundant natural resources waited to be discovered and environmental friendly and sustainably utilized. According to the considerations above, environment will be based on JONSWAP with gamma equals 3.3 which represents the normal situation.

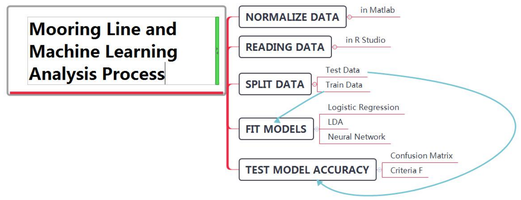


In this case, 4 different directions assumed to have similar results so only take one group of 3 lines as the main research object. Therefore 4 data groups would be obtained from "Intact", "Line 1 broken", "Line 2 broken" and "Line 3 broken" . After getting raw data from running the dynamic analysis, related postprocess is necessary as the data normalization in *Matlab*.

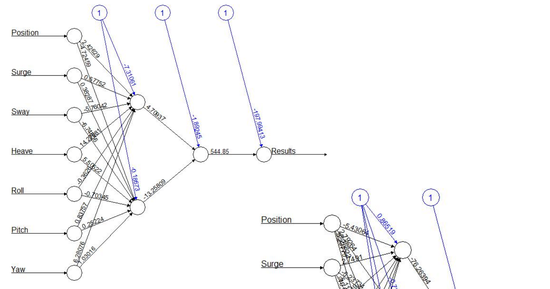


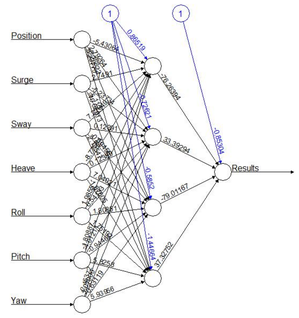
- ***Analysis***

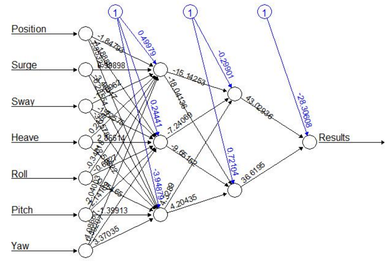
Data would be read in *R studio* as .csv file form. In this case, the results are assumed as binary, which 0 means intact and 1 means broken. Then split data into 2 parts as train and test from 2 purposes by a random number. Train data are used to fit different data models and test data would be used as refit to test the data model accuracy by creating a confusion matrix table from its prediction results.



Especially in the neural network model, in order to get a more accurate prediction, 3 different inner layer groups are used thus knowing better number of times of iteration calculation suitable for this case : 7 inputs and 1 outputs (binary). One inner layer configuration is set up as 2 layers consist of 3 nodes in first iteration and 2 nodes in another one separately. The other one is size as 2 - 1, and also make a single inner layer as 4 nodes.







Results

The numerical examing accuracy criteria here is *F* [2]. Theoretically, F closer to 1 is better.

$$F = \frac{2 * TruePositive}{2 * TruePositive + FalseNegative + FalsePositive}$$

And the *confusion matrix model* [2] of 4 different patterns machine learning models are seen as following, which the threshold prob chosen here is 0.5 for all the models as the best Bayes decision boundary. And in Neural Network, various thresholds are set to examine the accuracy.

Confusion Matrix		Prediction	
		Intact	Fatigue
Actual	Intact	True Negative(TN)	False Negative(FN)
	Fatigue	False Positive(FP)	True Positive(TP)

Logistic Regression		LDA		QDA	
86.27%	13.73%	81.97%	17.73%	83.69%	16.31%
2.74%	97.26%	0.86%	99.14%	1.54%	98.46%
F=0.9219		F=0.9143		F=0.9169	

Neural Network 3-2		Neural Network 2-1		Neural Network 4	
92.70%	7.30%	99.57%	17.73%	97.00%	3.00%
0.51%	99.49%	0.51%	99.49%	0.00%	100.00%
F=0.9622		F=0.9160		F=0.9852	

Conclusion

After comparing the results both from the confusion matrix and the criteria F, following conclusions could be obtained.

- Among 4 different kinds of machine learning models, the neural network has the best performance of prediction accuracy. Neural Network is a nonlinear method with high flexibility and could be the optimal option for analyzing the mooring line fatigue prediction.
- The best selection of the inner layer configuration in the neural network models, in this case the empirical one is proved to be the best choice, which is one layer with 4 nodes.
- Among different neural network configurations, especially double inner layers, the more complex one (3-2) which has more iteration steps performed better, but it still needs more massive data support and more experiments to figure out the best number of inner layers of the neural network method.
- Since LDA method has the smallest F, LDA would be the last choice in mooring line fatigue prediction.
- LDA and LR both produce linear decision boundaries, and though QDA has quadratic decision boundary but still more restrict. In this case these three models are underfit with high test prediction error rates.

Innovation

Comparing to previous researches, the innovative points could be summarized as :

① Sea state based on JONSWAP which takes the most extreme sea state as the research background.

② More raw data from different assumed situations : "Intact", "Line 1 Broken", "Line 2 Broken" and "Line 3 Broken".

③ More machine learning methods applied : Logistic Regression, LDA, QDA and Neural Network. Comparing the linear models and the nonlinear method to figure out which has more reliability from simulated data.

④ Different neural network configurations to figure out the better one.

References

[1] Igor Prislin, Soma Maroju, 2017. Mooring Integrity and Machine Learning, Offshore Technology Conference, Houston, Texas, USA, May 1-4 , OTC27866

[2] Vivek Jaiswal and Alex Ruskin, DNV GL, 2019. Mooring Line Failure Detection using Machine Learning, Offshore Technology Conference, Houston, Texas, USA, May 6-9 , OTC29511

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