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Masterarbeit

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Data-Driven Neural Network Approach to Corrosion Pit Identification and Classification

Datengetriebener neuronaler Netzwerkansatz zur Identifizierung und Klassifizierung von Korrosionsnarben

Wind energy, and other sustainable, renewable sources are pivotal to the future development of modern society, and thus, their continued and extended lifetimes are crucial. Offshore Wind Turbines (OWTs) pose a unique problem; due to their remoteness and proximity to water, they are highly susceptible to corrosion, as well as being difficult to inspect and maintain. With NetZero 2050 targets looming, this problem is only more ever-present. Corrosion, particularly localized pitting corrosion is critical for fatigue life as notches lead to stress concentrations [6–9]. By identifying pits and classifying their geometric properties, it is possible to determine stress concentration factors, and subsequently estimate the remaining fatigue life based on realistic condition of the components. From which, the necessity and location of maintenance work can be properly and promptly attributed. This project deals with the first step of this process: the identification and classification of corroded surfaces and the algorithmic determination of their geometric parameters, such as radius and depth of pits. Due to time constraint concerns and remoteness, this becomes an ideal candidate for data-driven surrogate approaches with fast inference times, in particular a deep neural network [2, 3, 10].

Given a 3D digital scan of the structure to be inspected as a 3D point cloud, in this master thesis, a neural network-based method is to be developed to detect pits and series of pits and to estimate the parameters describing their geometry. The creation of a heightmap from the point cloud data is a commonly applied intermediate processing step, that can optionally be incorporated here, too. Thus, this project aims to utilize computer vision and data-driven deep learning approaches in the field of fatigue corrosion and their proper coupling, in which the expected final output is a trained neural network capable of outputting the geometric properties of an identified pit or series of pits from previously unseen 3D digital scans. This is a collaborative effort between the Institute of Steel Construction and the Institute of Photogrammetry and GeoInformation.

The task can be divided into the following points:

- Literature review of computer vision, pit corrosion, and deep learning.
- Aggregation/Creation of a sufficiently large labeled dataset using processes and tools that already exist at the Institute for Steel Construction.
- Utilize data augmentation techniques to handle limited data sets.

- Development of a neural network architecture and a suitable training procedure in Python and JAX [1].
- Comprehensive evaluation of the results obtained with the developed method.

The following literature is recommended as a starting point to the topic, but is not remotely exhaustive:

[1] James Bradbury, Roy Frostig, Peter Hawkins, Matthew James Johnson, Chris Leary, Dougal Maclaurin, George Necula, Adam Paszke, Jake VanderPlas, Skye Wanderman-Milne, and Qiao Zhang. 2018. JAX: composable transformations of Python+NumPy programs. Retrieved from http://github.com/jax-ml/jax

[2] Kaiming He, Xiangyu Zhang, Shaoqing Ren, and Jian Sun. 2016. Deep Residual Learning for Image Recognition. In *2016 IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*, June 2016. IEEE, Las Vegas, NV, USA, 770–778. https://doi.org/10.1109/CVPR.2016.90

[3] Yann LeCun, Yoshua Bengio, and Geoffrey Hinton. 2015. Deep learning. *Nature* 521, 7553 (May 2015), 436–444. https://doi.org/10.1038/nature14539

[4] Dingkang Liang, Xin Zhou, Wei Xu, Xingkui Zhu, Zhikang Zou, Xiaoqing Ye, Xiao Tan, and Xiang Bai. 2024. PointMamba: a simple state space model for point cloud analysis. In *Advances in neural information processing systems*, 2024. Curran Associates, Inc., 32653–32677. https://doi.org/10.52202/079017-1026

[5] Guocheng Qian, Yuchen Li, Houwen Peng, Jinjie Mai, Hasan Hammoud, Mohamed Elhoseiny, and Bernard Ghanem. 2022. PointNeXt: Revisiting PointNet++ with improved training and scaling strategies. In *Advances in neural information processing systems*, 2022. Curran Associates, Inc., 23192–23204.

[6] Sulaiman Shojai, Tim Brömer, Elyas Ghafoori, and Peter Schaumann. 2024. Application of local fatigue approaches on corroded welded joints with consideration of weld geometry and residual stresses. *Theor. Appl. Fract. Mech.* 129, (February 2024), 104215. https://doi.org/10.1016/j.tafmec.2023.104215

[7] Sulaiman Shojai, Tim Brömer, Elyas Ghafoori, Christian Woitzik, Moritz Braun, Markus Köhler, and Peter Schaumann. 2023. Assessment of corrosion fatigue in welded joints using 3D surface scans, digital image correlation, hardness measurements, and residual stress analysis. *Int. J. Fatigue* 176, (November 2023), 107866. https://doi.org/10.1016/j.ijfatigue.2023.107866

[8] Sulaiman Shojai, Kram Kabha, Christian Woitzik, Moritz Braun, and Elyas Ghafoori. 2025. Fatigue behaviour of 12-month corroded offshore steel joints under accelerated salt spray exposure: an experimental and numerical analysis. *Weld. World* 69, 8 (August 2025), 2351–2369. https://doi.org/10.1007/s40194-025-02043-0

[9] Sulaiman Shojai, Peter Schaumann, and Tim Brömer. 2022. Probabilistic modelling of pitting corrosion and its impact on stress concentrations in steel structures in the offshore wind energy. *Mar. Struct.* 84, (July 2022), 103232. https://doi.org/10.1016/j.marstruc.2022.103232

[10] Xia Zhao, Limin Wang, Yufei Zhang, Xuming Han, Muhammet Deveci, and Milan Parmar. 2024. A review of convolutional neural networks in computer vision. *Artif. Intell. Rev.* 57, 4 (March 2024), 99. https://doi.org/10.1007/s10462-024-10721-6

Good Luck!

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