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Ship Structural
Design & Analysis

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PROJECT / MASTER THESIS

Analysis of ice bending experiments with statistics and machine learning

Prior to modeling, decisions on which and how to include phenomena and parameters in the (physics-based) model must be made. In other cases, the physics-based model is ready to use, but no measurements are available for necessary input parameters. The bending strength of ice is not itself a material property, but it reflects the maximum sustainable (tensile) stress in the ice. The flexural strength is an important and critical parameter for the performance of ice breaking ships or the break-up of ice due to waves. Therefore, many experiments have been conducted to determine the flexural strength, but results vary due to differences in test setup (size, cantilever beam, 3-point bending, 4-point bending) and ice properties (salinity, temperature etc.) [1, 2].

One remedy is to analyze correlation of parameters with outcome in experiments. For instance, is temperature an important parameter regarding the bending strength of ice? If yes, how can this parameter be included in models? How can a parameter value be obtained, if no measurements are available for a specific application?

An importance ranking of parameters is sought to support such decisions during modeling. Machine learning and statistical models can be used to establish such a ranking [3]. Furthermore, such models can calculate surrogate values for input parameters, if the real values are unknown.

In this thesis, a database of ice bending experiments should be established, for a start see e.g. [4–8] and references within. Once data is gathered, statistics and machine learning tools of your choice are to be used to analyze the data. Then, if the model is able to predict the outcome of experiments, the SHAP (SHapley Additive exPlanations) method should be used to understand the model predictions, see Fehler: Verweis nicht gefunden and [9] and the SHAP package on Github (https://github.com/slundberg/shap). In addition to the ranking, trends and interactions of the data driven prediction should be compared to state of the art ice mechanics knowledge, e.g. the relationship of bending strength and temperature or brine volume.

Remarks: No prior knowledge in machine learning or statistics is required. If this work is successful, a follow up publication in a journal is conceivable.

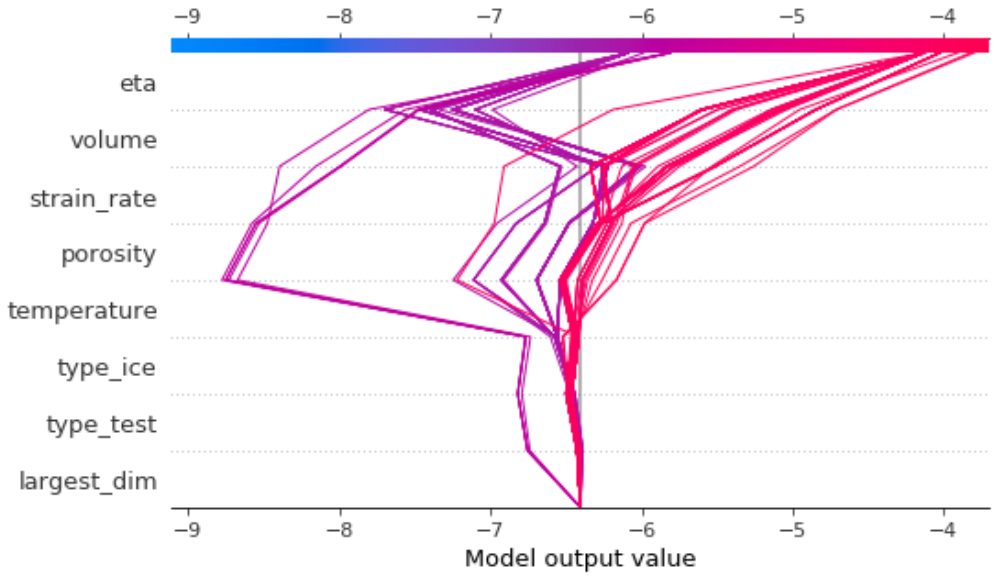

Figure 1 - Decision plot for 120 data points for strength prediction in compression (bar on the top in MPa, negative sign due to compression). The prediction starts at the bottom with the largest dimension of the specimen and is updated by including more features. Higher ranked features have more influence on the prediction. Something similar for bending strength should be one result of the thesis.

Work packages:

1. Literature review on ice mechanics regarding bending, and machine learning
2. Establish data base of bending experiments
3. Familiarize with existing tools and routines (available at our institute)
4. Implement methods of choice to predict e.g. bending strength
5. Interpret the model with the SHAP package and compare results to the state of art
6. Optional: include FE analysis to supplement existing data with e.g. fracture toughness values (FE models are available our institute)
7. Optional: statistic evaluation of results, e.g. with Weakest Link Theory

Tools:

- **Excel or similar** for initial database
- **Python with Jupyter lab or Spyder/Anaconda**, easy to use and beginner-friendly programming language with development environment of your choice
- **MATLAB,** additional analyses or post processing is preferably done with MATLAB.
- **ANSYS,** for possible, additional FE analyses

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Don’t hesitate to contact us if you are interested or have any further questions.

References

[1] M. Aly, R. Taylor, E. Bailey Dudley, and I. Turnbull, “Scale Effect in Ice Flexural Strength,” *J. Offshore Mech. Arct. Eng*, vol. 141, no. 5, p. 107, 2019, doi: 10.1115/1.4042388.

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Thesis format and general remarks

The work scope may prove to be larger than initially anticipated. Subject to approval from the supervisors, topics may be deleted from the list above or reduced in extent. In the thesis the candidate shall present his personal contribution to the resolution of problems within the scope of the thesis work. Theories and conclusions should be based on mathematical derivations and/or logic reasoning identifying the various steps in the deduction.

The thesis should be organized in a rational manner to give a clear exposition of results, assessments, and conclusions. The text should be brief and to the point, with a clear language and the objective to be published in a conference article and/or scientific journal.

It is thus desirable that the thesis is written in English. Telegraphic language should be avoided.

The thesis shall contain the following elements: An executive summary, table of content, list of symbols and acronyms, followed by the main body of the thesis consisting of a brief background introduction, a state of the art defining the knowledge gaps and the scope or work and limitations, the actual contribution chapters, conclusions with recommendations for further work, references and (optional) appendices. All figures, tables and equations must be numerated.

The supervisors require that the candidate, in an early stage of the work, presents a written plan for the completion of the work. The plan may include a budget for the use of computer and laboratory resources if applicable, which will be charged to the department. Overruns shall be reported to the supervisors.

The original contribution of the candidate and material taken from other sources shall be clearly defined following basic academic principles and an acknowledged referencing system, which includes the name of the referred authors followed by the publication year in the text.

The report shall be submitted in two copies:

- A signed statutory declaration must be included
- The text defining the scope must be included
- In bound volume(s)
- Drawings and/or computer prints, which cannot be bound should be organized in a separate folder.
- The report shall be submitted in PDF along with essential input files for computer analysis, spread sheets, MATLAB files etc. in digital format

Ownership

See appended document regarding ownership and copyright of the thesis.

Deadline:

Hamburg,