Lehrstuhl Steuerung,
Regelung und Systemdynamik

Master Thesis

Literature, Experimental

Classification of damage mechanisms using Deep Learning and features from time domain

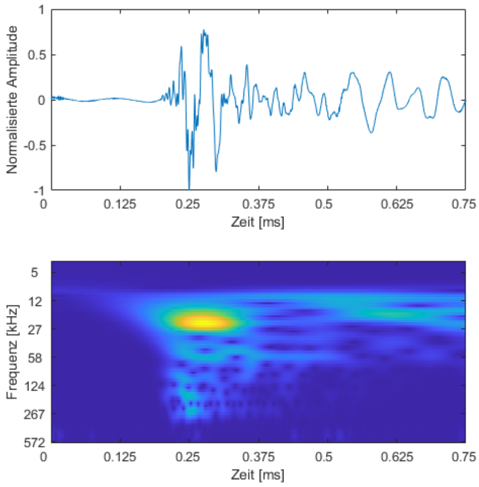
Keywords: classification, deep learning

Conditions:

Duration:	6 months
Submission until:	30.03.2026
Requirements:	Programming skills in MATLAB
Language:	English/German
Target group:	Master students

Contents:

Acoustic Emission (AE) is a non-destructive testing method enabling in-situ monitoring of structures and materials. When a damage event occurs, part of the released energy is transformed into ultrasonic waves, which can be detected using piezoelectric transducers mounted on the structure's surface. Each type of damage generates an AE signal with specific characteristics in the time, frequency, and time–frequency domain.



Acoustic Emission Event im Zeit- und Zeit-Frequenzbereich

The aim of this thesis is to develop a classification framework for AE signals using only features from time-domain. A literature review is to be conducted covering, time-domain feature extraction techniques, deep learning methods for signal classification, and suitable evaluation metrics. The provided dataset is to be analyzed and preprocessed before extracting discriminative time-domain features from the raw signals. Based on these features, a deep learning model is to be designed and implemented to classify the signals into the four damage classes. The performance of the model is to be evaluated using established metrics, and misclassifications are to be analyzed to identify weaknesses and areas for improvement. If necessary, the feature set and model architecture are to be refined to enhance classification accuracy.

The goals of this work are:

- Conduct a literature review on Acoustic Emission analysis, time-domain feature extraction, deep learning methods for signal classification, and model evaluation approaches
- Analyze and preprocess the provided AE dataset
- Extract time-domain features from raw signals to characterize different damage mechanisms
- Design and implement a deep learning model for multi-class classification of AE signals
- Evaluate the classification performance using standard metrics and analyze misclassifications
- Refine features and model architecture to improve classification accuracy
- Complete and detailed documentation/presentation of the research results

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Methodology

1. Literature Review – Study relevant work on Acoustic Emission analysis, time-domain feature extraction, deep learning approaches for time-series classification, and suitable evaluation metrics.
2. Data Preprocessing – Analyze the provided AE dataset, perform normalization, remove noise, and segment signals if necessary to ensure consistent input quality.
3. Feature Extraction – Derive discriminative features directly from the time domain (e.g., amplitude patterns, rise/fall times, energy, zero-crossing rate, statistical descriptors).
4. Model Design – Develop a deep learning architecture (e.g., CNN, RNN, or hybrid network) to process the extracted features and classify AE signals.
5. Training and Validation – Train the model on the dataset using appropriate data partitioning strategies such as k-fold cross-validation or train/validation/test splits.
6. Performance Evaluation – Assess the model using standard classification metrics, including accuracy, precision, recall, F1-score, and confusion matrices.
7. Error Analysis – Analyze misclassified signals to identify weaknesses in the feature set or the model architecture.
8. Model Refinement – Improve classification accuracy through iterative refinement of features, hyperparameters, or model architecture.

Expected Results

- A functional classification framework for AE signals based exclusively on time-domain features.
- A systematic evaluation of different time-domain features and their contribution to classification performance.
- A trained deep learning model capable of distinguishing between the four damage classes: delamination, debonding, matrix cracking, and fiber breakage.
- Quantitative results demonstrating classification performance through standard metrics.
- Insights into limitations of time-domain-only methods compared to frequency-based approaches.
- Recommendations for further improvements in feature extraction and model design.
- A validated and documented pipeline that can serve as a basis for real-world structural health monitoring applications.

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