# Lehrstuhl Steuerung, Regelung und Systemdynamik

## Master Thesis

*Programming*

## Machine learning-based modeling and simulation of ultrasonic wave propagation using step-wise optimization

*Keywords: Guided Waves, Machine Learning, wave simulation*

**Conditions:**

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| Duration: | 6 months |
| Requirements: | MATLAB knowledge |
| Language: | English or German |
| Target group: | Master students |

**Contents:**

In the context of Structural Health Monitoring (SHM), guided waves are widely used as a non-destructive testing method. Ultrasonic waves are generated by actuators and propagated through the monitored structure. Damage assessment is then performed by analyzing changes in the received signals. However, the complex propagation behavior of ultrasonic waves in carbon fiber reinforced plastics (CFRP) significantly increases the difficulty of analysis.

The goal of this master thesis is to extend and optimize the MSD-based simulation framework by introducing a step-wise optimization approach. Instead of optimizing the full actuator–sensor network at once, the method will iteratively optimize smaller structural sections corresponding to individual actuator–sensor paths and combine them to achieve an accurate system-wide model. The training and test data will be taken from an open-source dataset, which contains experimental measurements from a composite panel representing the lower part of a wing box. The existing simulation approach is based on particle swarm optimization (PSO), which optimizes the mass, spring stiffness, and damping coefficients of a double-layer MSD network. The MSD network takes the experimental excitation signal as input and outputs a simulated response, which is compared against the measured sensor signal to assess the accuracy of the simulation. This thesis will focus on a step-wise optimization approach for the entire wing box structure by separately optimizing the sections between individual actuator–sensor pairs.

Sensor placement on the wing box [Marzani et al., 2019]

Goals of the thesis:

- Analyze and extend the existing MSD-PSO framework
- Preprocess and feature-extract ultrasonic measurement data
- Implement and test a step-wise optimization strategy
- Adapt MSD parameters to real CFRP measurements
- Validate the model with multiple test cases. Verify the model adaptation through multiple test cases and prediction evaluation
- Complete and detailed documentation/presentation of the research results


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