

## Master thesis Magnetic material meta modeling

Magnetic components are integral to modern power electronics, but are generally the most bulky part. With the continuous trend towards efficiency and sustainability, the question on how to properly optimize such components becomes more prominent. The main issue is that modeling the behavior of such components is rather difficult due to saturation and hysteresis effects. For steady-state, models are already being researched. However, for transient behavior (see Fig. 1a for an exemplary prediction task), models are still poorly developed. There is increased interest due to the MagNet Challenge 2 (MC2) and an adequate data set has been provided in the context of the challenge [1]. To support the trend towards more accurate and efficient models of magnetic material, it should be evaluated within the scope of this thesis to what degree models for the prediction of transient material behavior can be transferred between materials and if it is possible to build meta models (MMs) that can provide accurate predictions over a wide range of materials (see Fig. 1b).

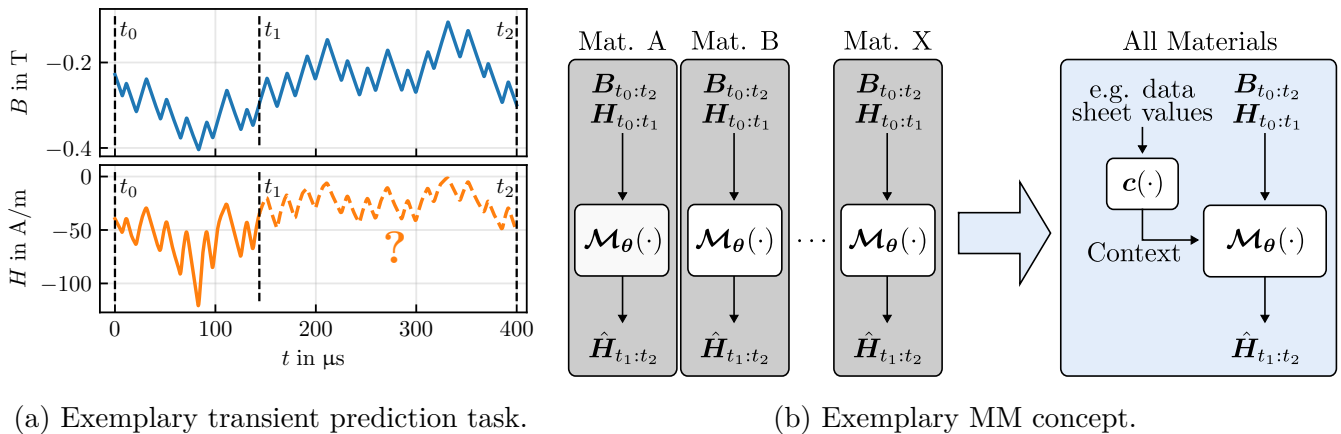


Figure 1: Task overview.

### Key research questions:

- What accuracy on predicting unseen material data can be achieved/is to be expected when predicting material behavior with a MM, that was trained on data from other materials?
- What extra information needs to be provided for context? Can the context be derived directly from trajectory data for this purpose?

### Necessary requirements:

- Good programming skills in a scientific programming language (Python or Julia)
- Finished course work on machine learning
- Experience with a machine learning framework (e.g., JAX, PyTorch, TensorFlow, Flux)

**WP 1: Literature research****[4 weeks]**

Scanning the scientific literature for relevant publications and patents related to magnetic transient modeling and meta modeling and related fields is the first step. Relevant work will be stored in a literature review software (e.g., JabRef) and summarized in the thesis. Additionally to the literature, the data as well as the results and submissions for the MC2 <https://github.com/minjiechen/magnetchallenge-2> should be considered and studied. Especially, it is advised to consider the submission from the IAS group <https://github.com/upb-lea/RHINO-MAG/>, understand its structure, and do first tests with it.

**WP 2: Material to material****[2 weeks]**

Investigate how well models that were trained on one material, perform when applied on another material. Interesting questions are, how the material data should be normalized and what materials work well together. Form first ideas, what grouping can be found in the materials.

**WP 3: MM without context****[3 weeks]**

In theory, a large enough RNN should be able to find context directly from trajectory data. Within this WP, a baseline model is to be built, that does not have any explicit context generation, but is just trained on mixed material data without explicitly knowing about the differences.

**WP 4: Context tests****[3 weeks]**

Investigate different ideas for context generation. Incorporate your findings from WP 2. Ideas could be based on providing context from material data through an additional RNN, or static mappings from data sheet values to a context via MLPs.

**WP 5: MM with context****[4 weeks]**

Combine the previously investigated context generators with the MM developed in WP 3 to produce a context-aware MM.

**WP 6: Pareto front****[4 weeks]**

Evaluate the models for different sizes and decide on proper parameterization via cross-validation.

**WP 7: Documentation****[6 weeks]**

All work packages should be reported in a structured way within the thesis. A LaTeX template should be used for this purpose: [https://github.com/IAS-Uni-Siegen/thesis\\_latex\\_template](https://github.com/IAS-Uni-Siegen/thesis_latex_template) Writing instructions can be found within the provided template source files. Based on the previous empirical findings, conclusions should be drawn, and future research directions should be outlined.

## Gantt chart

The planned timetable is shown in the Gantt diagram below.

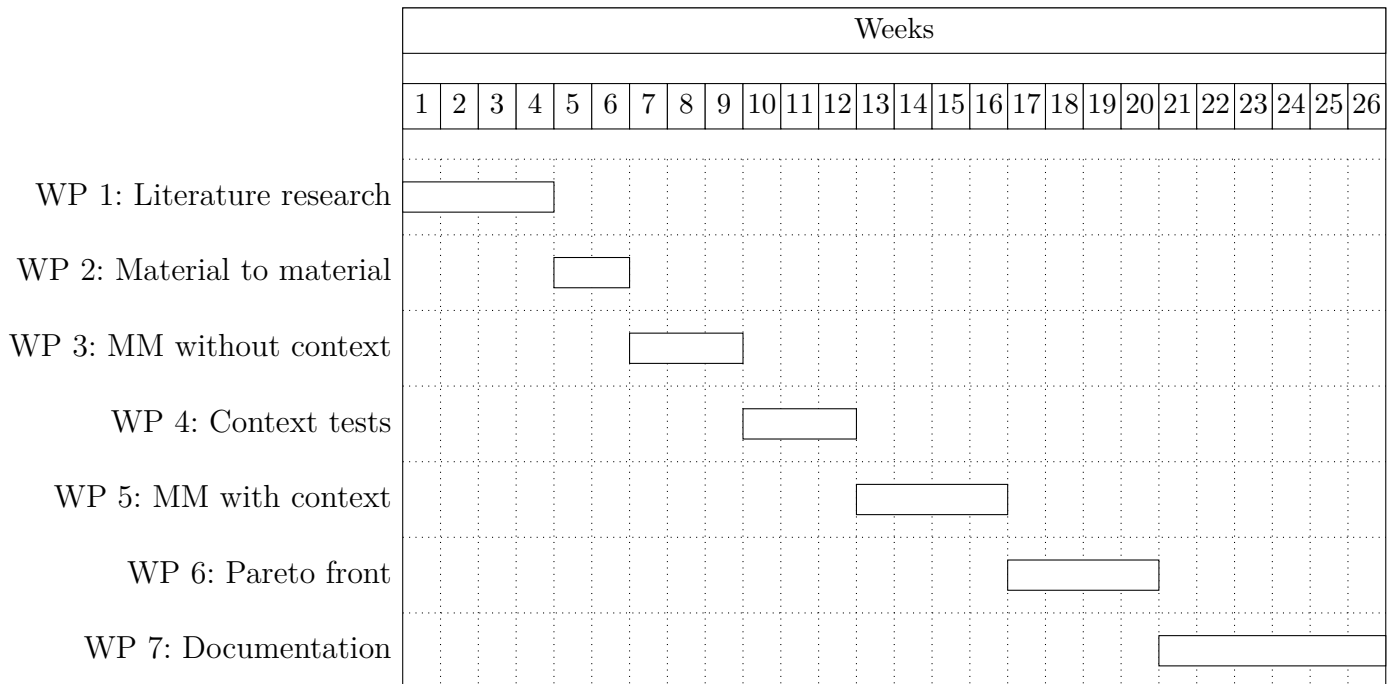


Figure 2: Gantt chart for the thesis.

## References

- [1] H. Kwon, S. Wang, H. Li, Y. Elasser, G.-G. Kang, D. Zhou, D. Grigoryan, and M. Chen, “Magnetx: Extending the magnet database for modeling power magnetics in transient,” in *2025 IEEE Applied Power Electronics Conference and Exposition (APEC)*, 2025, pp. 566–572.