FM@KUL-E2E

Multi-model fusion for inverse problems

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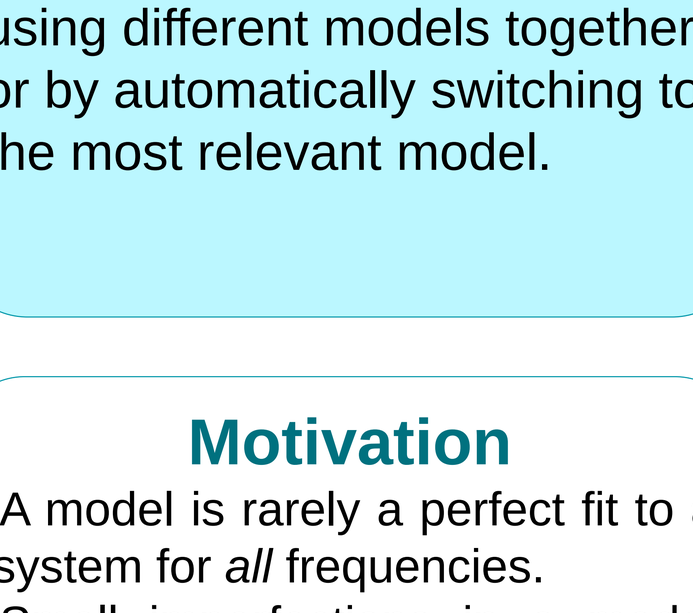
Digitized Products enabling end-to-end design-operation

Goal

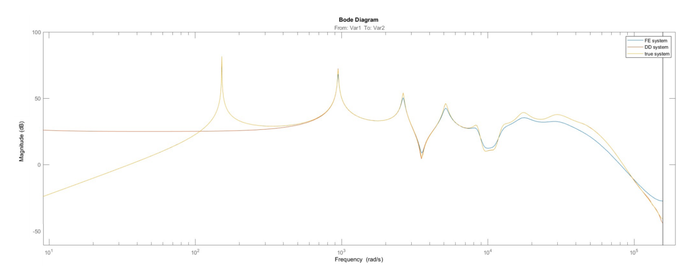
The goal is to use multiple models of the same system for inverse problems to improve the accuracy of the result. Whether by simultaneously using different models together or by automatically switching to the most relevant model.

Motivation

- A model is rarely a perfect fit to a system for *all* frequencies.
- Small imperfections in a model can drastically change its accuracy (ref1).



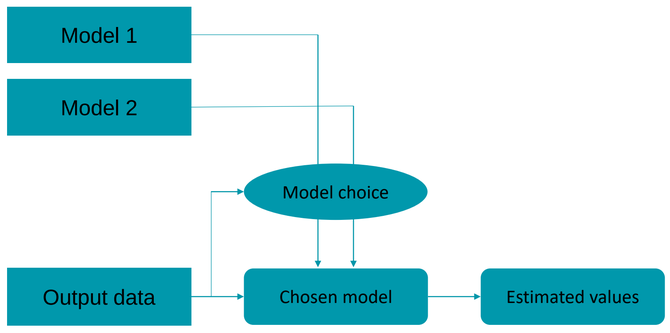
- Often, several models are available for the same system. Each model has its useable frequency range.
- For example, a finite element model and a data driven model:



- Therefore, it would be beneficial to utilize multiple models to get a broader useable range,

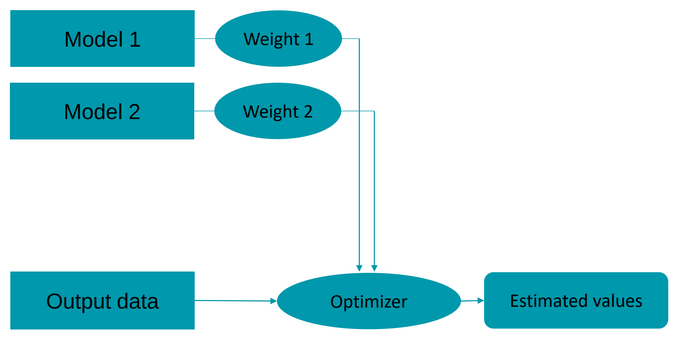
Approach

- Several different approaches can be considered:
  - Keeping the models separated:
    - Use one model at a time
    - Automatically change models
    - Model choice for each frequency separately

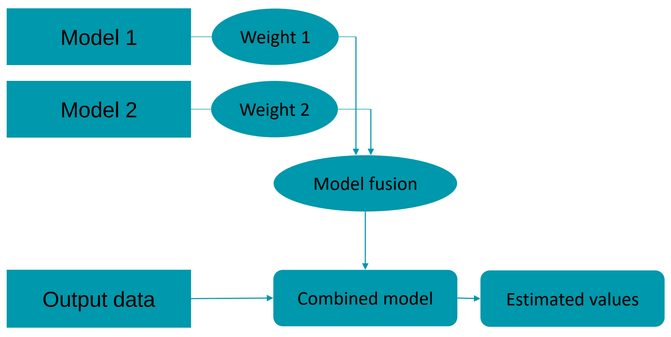


- Using models simultaneously:
  - Formulate weighted optimization problem
  - Each model has a weight for each frequency

$$\min_{U^f} \sum_i \left\| W_i \left(Y^f - H_i^f U^f \right) \right\|_2^2$$



- Combining models:
  - Create new model using others
  - Possible weight per frequency

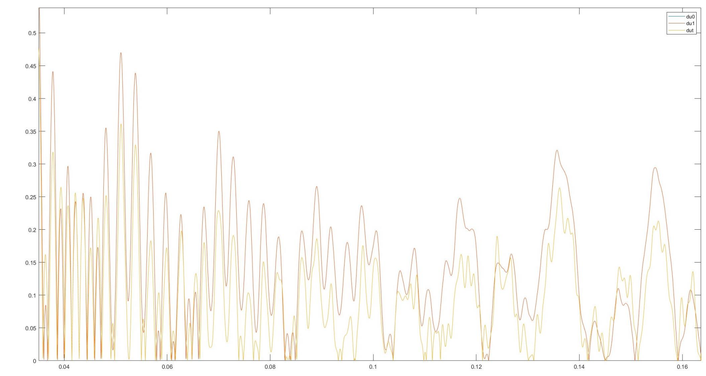


Results

- For the second approach, solving the optimization problem results in the following equation:

$$U^f = \left(\sum_i \left(H_i^f \right)^T W_i^2 H_i^f \right)^\dagger \left(\sum_i \left(H_i^f \right)^T W_i^2 Y^f \right)$$

- Using this equation, the following result was obtained:



- This proof of concept shows that combining models can work.
- Further refinement of this approach should improve the results.
- Comparing different approaches will show their respective (dis)advantages.

Key take-aways

- All models are flawed and of limited use. Combining models can thus prove useful to improve accuracy.
- Large errors due to small mismatches in a model can be negated by other models.
- Several approaches are possible and should be compared.

Further reading

- ref1: Zapata L., Patalong M., Teufelhart S., Desmet W. & Naets F. (2022). Combined impulse-response/Kalman filtering (CIRKF) for input/state estimation https://doi.org/10.1016/j.ymssp.2022.109527

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For Publication