Spectral model fusion for force input reconstruction

Brecht Geutjens, Karl Meerbergen, Frank Naets

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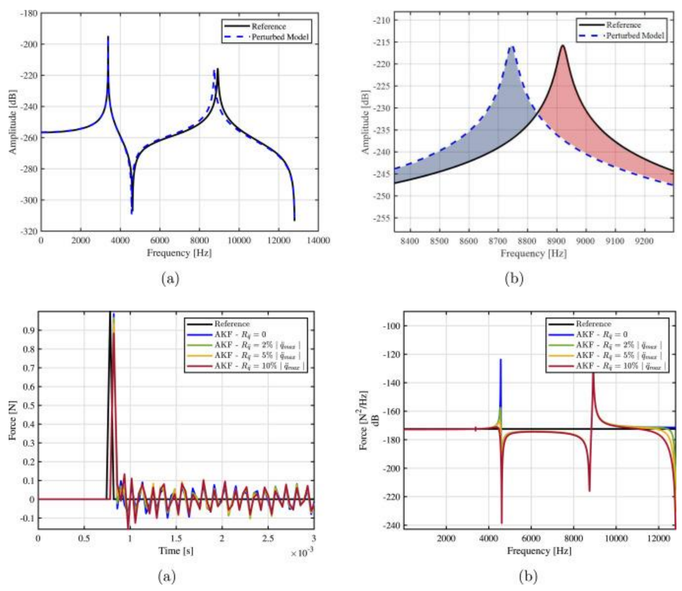
Goal

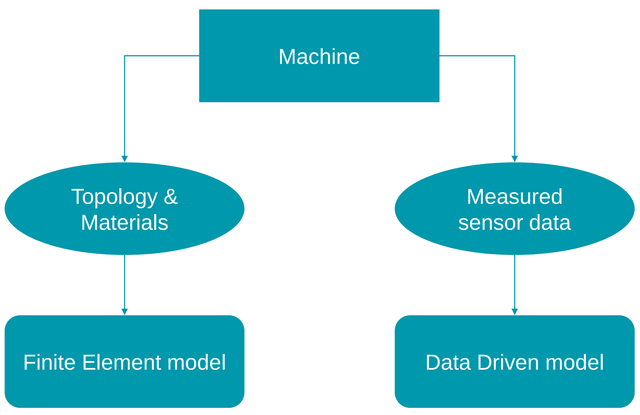
To improve the accuracy of inverse problems, such as force reconstruction in mechanical systems, through simultaneous usage of multiple models of the same system.

Motivation

- Forces are hard or expensive to measure, so they are often estimated instead.
- Models are imperfect.
- Inverse problems are known to be very sensitive to modelling errors: [1]



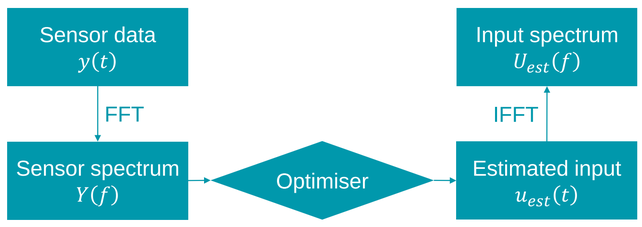
- All available information is thus useful to improve accuracy.
- Often, multiple models are available:



- FE models are better for low frequencies and DD models for high frequencies.
- Using each model in its accurate frequency range could improve results.
- Therefore, we propose to do force input reconstruction in the frequency domain.

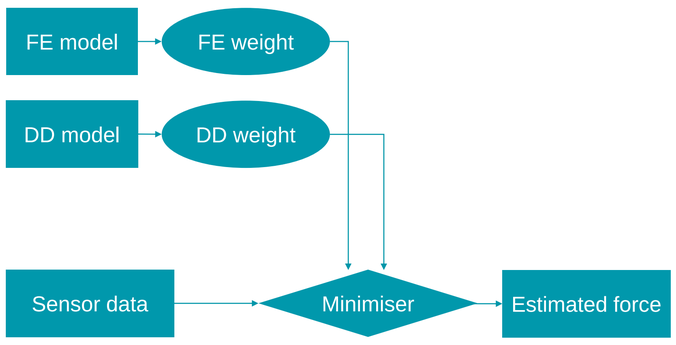
Approach

- Move sensor data to frequency domain, optimize input spectrum and return to time domain:

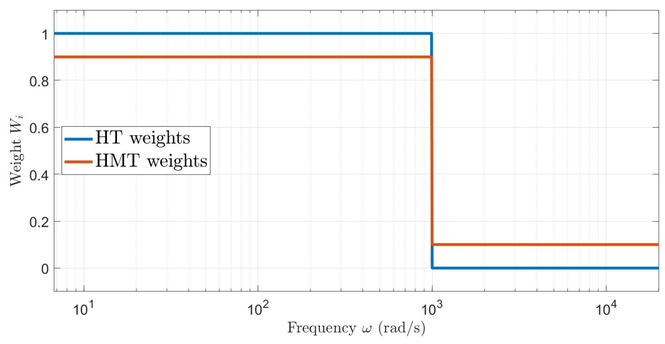


- Optimiser: Minimise weighted output error, summed over both models:

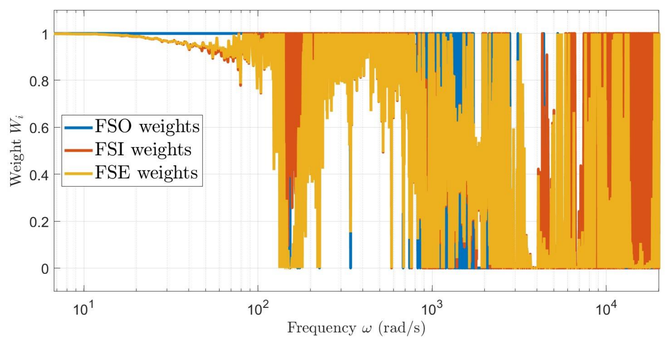
$$\min_{U_{est,f}} \sum_{m} W_f^m \left\| \left(Y_f - H_f^m U_{est,f} \right) \right\|_2^2$$



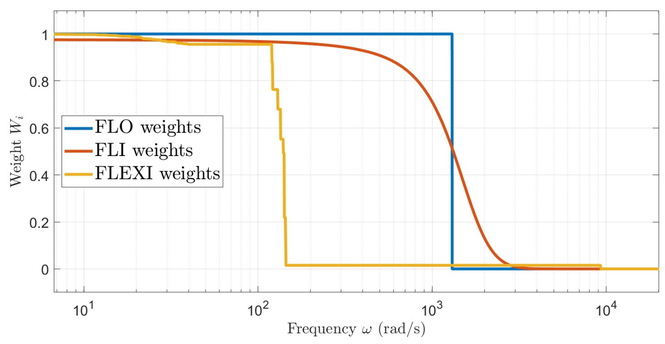
- Weights need to be chosen. Several approaches possible:
- Heuristically choosing:



- Optimizing with training data:

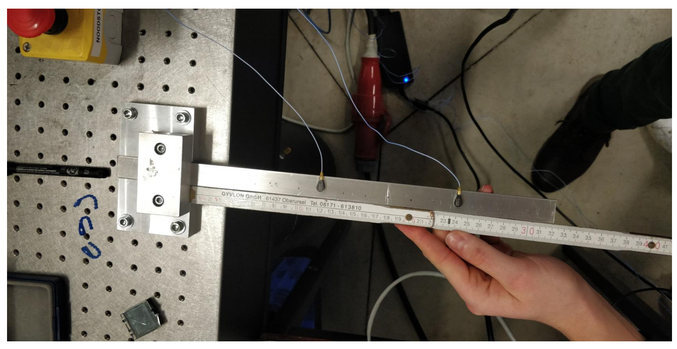


- Assuming sigmoid:

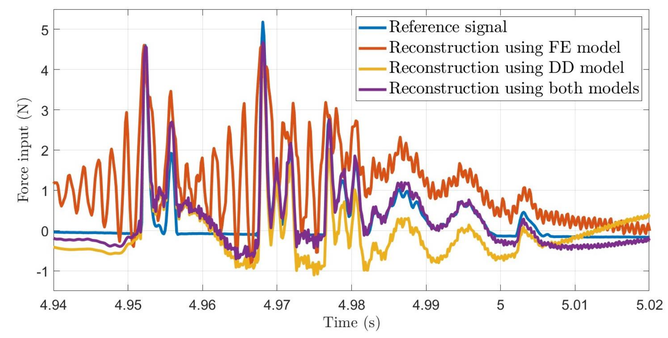


Results

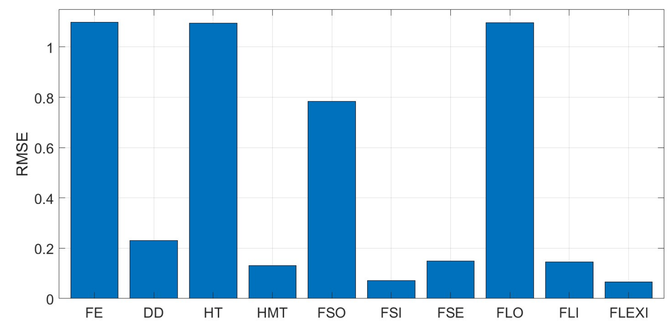
- Academic example test setup:



- Model fusion concept validation:



- Weighting scheme RMSE value comparison:



Key take-aways

- Small modelling errors allow for large errors in inverse problems.
- Multiple models are available.
- Simultaneous usage of different models limits the errors due to inverse problem sensitivity.
- A new method was developed and performs well, depending on the chosen weights.
- More methods following the model fusion approach should be designed, tested and compared to the SOTA.

Further reading

- [1]: 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
- Geutjens B., Meerbergen K. & Naets F., “A spectral model fusion approach for force input estimation” (Future journal publication, working title)

brecht.geutjens@kuleuven.be

Poster 106

For Publication