Control-focused identification of hysteretic systems: Selecting model structures? Think about the final use of the model!

Control-focused identification of hysteric systems

Selecting model structures? Think about the final use of the model!

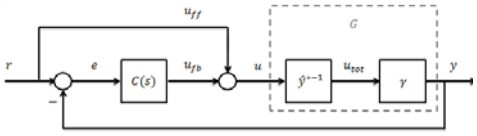
Rolf Gaasbeek
Eindhoven University of Technology
R.I.Gaasbeek@TUe.nl

Rishi Mohan
Eindhoven University of Technology
R.Mohan@TUe.nl

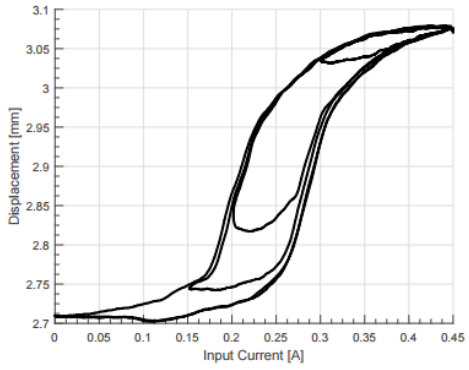
System identification techniques utilize data to create a mathematical model of a dynamical system. Typically, during the identification process specific model structures or basis-functions are selected. It is important to realize that identified models are often afterwards used to design or analyse a controller. Therefore, it is wise to use information about the controller -structure and -objectives to select an appropriate model structure.
In this work, identification of hysteric systems is discussed. It is proposed to stay limited to the class of invertible models, as inverted hysteric models are often used in control procedures for systems that suffer from hysteresis. Lastly, an identification-based analysis is proposed to compare performance of invertible models.

1 Proposed Approach

To illustrate how the inverse of a mathematical model can be used in control design, an example control-scheme is shown in Figure 1.



The proposed control approach relies on the availability of an accurate model $\hat{\gamma}$ of the system γ, of which an (approximate) inverse $\hat{\gamma}^{*-1}$ exist. Thus, to allow for control-focused identification, only invertible model structures should be considered. For simplicity, this work limits itself to the Duhem model [1]; a nonlinear dynamic hysteresis model that is dependent on only 4 parameters. In [2] an approximate inverse of the Duhem model has been derived.



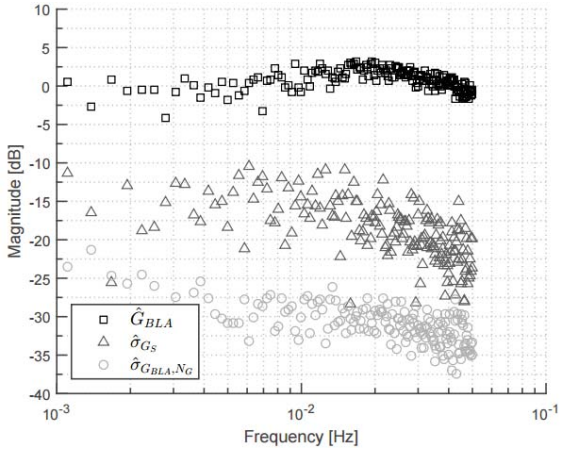
Although less suited for the Bouc-Wen model, the model-functions are adopted from [1], and thus are optimized for Shape Memory Alloy actuation. More research should be done on suitable invertible Bouc-Wen models.

2 System Identification

The *lsqcurvefit* function in Matlab is used to (sub)optimal find the parameters of the Duhem model. The validation set for the Shape Memory Alloy actuator is shown in Figure 2; the hysteresis behavior is clearly visible. The identified mathematical model is able to predict the output of the actuator with a maximum RMS error of 0.05 mm. Unfortunately, the model structure chosen in Section 1 proved to be not rich enough to capture the behavior of the Bouc-Wen model.

3 Identification-based Analysis

The control approach as derived in Section 1 is dependent on the quality of both the model as well as the inverse. In practice, both are not perfect. Thus, the mapping between u and y (denoted G), is not equal to identity.



The robust method [3] is used to find both a linear approximation (black ○) and non-linear distortions (grey △) of G. If the linear approximation is not equal to 0dB, the inverse is degraded; the feedback controller can be designed accordingly. However, non-linear distortions are significantly more difficult to take into account with the controller-design. Therefore, from a control perspective, the proposed inverse validation is preffered over classical inverse analysis approaches, such as looking at the RMS value on the error.

References

[1] S. M. Dutta and F. H. Ghorbel, "Differential hysteresis modeling of a shape memory alloy wire actuator," *Mechatronics, IEEE/ASME Transactions on*, vol. 10, no. 2, pp. 189-197, 2005.

[2] S. M. Dutta, F. H. Ghorbel, and J. B. Dabney, "Modeling and control of a shape memory alloy actuator," *Intelligent Control*, 2005.

[3] R. Pintelon and J. Schoukens, "System Identification: A Frequency Domain Approach," *IEEE Press, Piscataway, NJ*, 2001.