## MiMM Day 2025: Challenges with interloping models for adhesive development – Uncertainty quantification and error propagation

Adhesive tapes are used in everyday life as well as in many technical applications. Often, and especially in industrial applications, the virtual design of components and complex systems has become a routine task for product developers. Virtual development is supported by prediction of various methods. The mathematical foundation for this is manifold. Using those methods we are faced with problems:

I. We need to derive reliable principal prediction models to map data set $y_i$ to $y_{i+1}$ using a mapping function $f_i$ parameterized by the parameter set $p_i$.

II. Once found, we need to calibrate $f_i$ via $p_i$ by solving an optimization problem:
Find $p_i$ such that for data sets and $y_i$, $y_{i+1}$ and a given error functional $r$,

$$r(y_i, y_{i+1}) = \|f_i\ (y_i, p_i) - y_{i+1}\|_2 \text{ is minimal.}$$

III. The optimization problem is disturbed due the experimental data is prone to scatter in the data instead of “perfect” data sets $y_i$ and $y_{i+1}$, we receive data from experiments such that

$$y_i^{exp} = y_i + \varepsilon_i \text{ and } y_{i+1}^{exp} = y_{i+1} + \varepsilon_{i+1}$$

Whereas $\varepsilon_i$ resp. $\varepsilon_{i+1}$ reflect the scatter in the data. This raises the question, depending on the calibration data which parameters $p_i$ do we have to expect? Can we quantify the scatter on $p_i$ based on known scatter on the input data?

IV. In virtual product developments we try to reduce the number of experiments drastically, so we like to model dependency over many levels, meaning, we like to predict the following:

$$y_{i+1+n} = f_{i+n}(f_{i+n-1}(f_{i+n-2}(\dots f_0(y_0, p_0) \dots, p_{i+n-2}), p_{i+n-1}), p_{i+n})$$

Can we quantify the error quantification over several levels?

V. The ultimate goal is to find the optimal $y_i^{opt}$ to fulfil a wanted $y_{i+1}^{opt}$.
Find $y_i^{opt}$ such that for given $f_i$ , $p_i$, $y_{i+1}^{opt}$ and a given error functional $r$,

$$r(y_i, y_{i+1}) = \left\|f_i\left(y_i^{opt}, p_i\right) - y_{i+1}^{opt}\right\|_2 \text{ is minimal.}$$

The interloped relation of (IV.) applies instead, too. Note here, $p_i$ is found based on scatter data in the calibration. How reliable is $p_i$? Can we quantify a scatter for $y_i^{opt}$?

Starting, we could look at linear functions $y_{i+1} := f_i(y_i) = a_i \cdot y_i + b_i$, and artificially scattered data.

The tesa SE team will be happy to discuss this challenging modelling task with you!

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