Interdependent Intervals: Multivariate and Spatial Uncertainty Analysis Under Scarce Data

Matthias Faes* MATTHIAS.FAES@KULEUVEN.BE
David Moens DAVID.MOENS@KULEUVEN.BE
KU Leuven, Department of Mechanical Engineering, Belgium

In an engineering context, structural design optimization is usually performed virtually, based on numerical models to approximate the underlying (sets of) partial differential equations that describe the physical behaviour of the structure. However, valid criticism exists with respect to such approach, as more often than not, only partial or uninformative data are available to estimate the parameters that feed into these numerical models. This is a direct result from either practical or strategical limitations in gathering the necessary data to estimate the parameter values, the inherent variability in these parameters, or a combination of both. As a result hereof, the results that are obtained by such numerical approximation can diverge significantly from the real structural behaviour of the design, as quantified by e.g., experimental measurements. Under such scarce data availability, especially interval analysis has been proven to provide an analyst with robust bounds on the structural behaviour, often at a small-to-moderate computational cost [4].

This poster will highlight recent developments in the field of interval analysis with an emphasis on the effective and efficient modelling of dependence between multiple intervals and interval fields. The following aspects will be treated:

- Classic interval analysis is incapable of dealing with dependence, as it by definition represents multi-dimensional interval uncertainty via Cartesian products [4]. Such approach is for instance problematic when dealing with intra-domain uncertainty, as in this case a lack of dependence between multiple intervals within the model domain yield physically unrealistic predictions. In this context, interval fields [5, 1] have been introduced as a non-probabilistic counterpart of random fields. This poster provides a rigorous explanation of this concept with an extension towards imprecise random fields.

- When multiple interval scalars or fields have to be considered in the same model, it has been until now not possible to account for any joint dependence between such scalars and fields. Recent work by the authors introduced a framework based on the concept of Vine Copula in an interval context [3] to account for such dependence in a highly flexible way. This work will in this poster also be extended towards the model of cross-dependence between interval fields, based on initial work [2].

References

[1] M. Faes and D. Moens. Identification and quantification of spatial interval uncertainty in numerical models. *Computers and Structures*, 192:16–33, nov 2017. doi:10.1016/j.compstruc.2017.07.006.

[2] M. Faes and D. Moens. On auto-and cross-interdependence in interval field finite element analysis. *preprint submitted to Wiley*, 2019. doi:10.13140/RG.2.2.33272.08966.

[3] M. Faes and D. Moens. Multivariate dependent interval finite element analysis via convex hull pair constructions and the Extended Transformation Method. *Computer Methods in Applied Mechanics and Engineering*, 347:85–102, dec 2019. doi:10.1016/j.cma.2018.12.021.

[4] M. Faes and D. Moens. Recent trends in the modeling and quantification of non-probabilistic uncertainty. *Archives of Computational Methods in Engineering*, feb 2019. doi:10.1007/s11831-019-09327-x.

[5] W. Verhaeghe, W. Desmet, D. Vandepitte, and D. Moens. Interval fields to represent uncertainty on the output side of a static FE analysis. *Computer Methods in Applied Mechanics and Engineering*, 260:50–62, 2013. doi:10.1016/j.cma.2013.03.021.

* Matthias Faes is a post-doctoral researcher of the Research Foundation Flanders (FWO) under grant 12P3519N)