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Identification of the probability density function of a dimension from samples with measurement errors

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Various scientific and engineering applications rely on the collection of data, which is subsequently processed and utilized for decision making. In this context, the accuracy of measurements plays a crucial role in ensuring the quality and reliability of the entire process. Unfortunately, measurements are often prone to inherent errors that can significantly impact the precision of the results. This paper introduces a method to effectively account for and, to some extent, correct such measurement errors, acknowledging that they cannot be entirely avoided.

The approach adopted in this study is probabilistic in nature, wherein Probability Density Functions (PDF) are utilized to describe both the collected data and the measurement errors. Specifically, the focus of this paper is on identifying the PDF associated with the true value of the collected data, thereby rectifying the effects of the measurement errors. An additive error is considered here and the PDF of the collected data is involved in the well-known formula of the sum of two independent random variables. The PDF of the measurement error is here assumed to be known.

The proposed method takes the collected data as its input, which consists of a set of realizations encompassing the measurement errors. The PDF associated with this data can be identified (using e.g. the maximum of likelihood, kernel density estimation, etc.).

The focus of this paper is the identification of the PDF associated with the collected data. This PDF lays within an integral and its identification is therefore a challenging task; this operation is here referred to as a deconvolution, as an analogy with signal processing. It is not possible to apply the traditional integration strategies, such as e.g. Monte Carlo simulation or Gauss' integration scheme. Indeed, the integral would be transformed into a sum, where each term – the PDF of the true value – is unknown. An alternative strategy is proposed here, based on a local approximation of the PDF to circumvent this issue.

Keywords: Measurement errors, Uncertainty Quantification, Deconvolution.