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Parameter Determination of Sensor Stochastic Models under Covariate Dependency

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The proliferation of (low-cost) sensors provokes new challenges in data fusion. This is related to the correctness of stochastic characterization that is a prerequisite for optimal estimation of parameters from redundant observations.

Different (statistical) methods were developed to estimate parameters of complex stochastic models. To cite a few, there is the maximum likelihood approach estimated via the so-called EM algorithm as well as a linear regression approach based on the log-log-representation of a quantity called Allan Variance. Nevertheless, all these methods suffer from various limitations ranging from numerical instability and computational inefficiency to statistical inconsistency. The relative recent approach called Generalized Method of Wavelet Moments (GMWM) that makes a use of the Wavelet Variance (WV) quantity of the error signal was proven to estimate stochastic models of considerable complexity in a numerically stable and statistically consistent manner with good computational efficiency.

The situation is more challenging when stochastic errors are dependent on external factors (e.g. temperature, pressure, dynamics). This paper presents the essence of mathematical extension of the GMWM estimator that allows handling such a scenario rigorously by taking the external influences into consideration.

We present the model of the multivariate stochastic process that composes firstly of the process of interest (signal of a sensor) and secondly of an explanatory process (e.g. environmental variable), where the latter is believed to have an impact on the stochastic properties of the former. Next, we assume that the input is composed of a real-valued "smooth" function dependent on external influence (values of which are perfectly observed) and a zero-mean process that is itself a sum of several independent latent processes. Then we define the covariate-dependent latent process (e.g. change of variance of white noise or auto-regressive process) as a class of piece-wise covariate-dependent latent time series models described by n-parameters. We propose to estimate the underlying vector parameter of interest using a modified version of the GMWM methodology that considers linear approximation of the dependency between noise parameters and the external influence. The intuition behind the new GMWM estimator is to select the parameter values that match the empirical WV on the data with the theoretical WV (i.e. those generated by the model parameters). We briefly demonstrate the asymptotic properties of the estimated parameter vector as well the consistency of the estimator.