Prediction of uncertain structural responses with fuzzy time series

Bernd Moeller, Uwe Reuter

The prediction of future structural responses is a challenging problem in civil engineering. The knowledge of unknown future impact and future system behavior enable the prediction of such important effects like damage behavior, development of safety level, development of durability or the expected life time of a system. The well established numerical structural analysis and safety assessment however presuppose the knowledge of adequate theoretical models.

As alternative fuzzy time series can be applied. They describe sequences of measurements consisting of imprecise data. The uncertainty of the imprecise data is modeled as fuzziness. Time series with fuzzy data are regarded as realizations of a fuzzy random process, that can be viewed as a random process extended by the dimension fuzziness. In extension to a random process a fuzzy random process is defined as a sequence of fuzzy random variables. Therein, a fuzzy random variable is declared as set of uncertain realizations (fuzzy variables) in the space of the random elementary events. Each realization of a fuzzy random process then appears as a fuzzy function, which characterizes a sequence of fuzzy variables. In other words time series with fuzzy data can be interpreted as random realization of an underlying fuzzy random process.

Methods for identification and quantification of the underlaying fuzzy random process are presented. A new description of fuzzy variables by so-called increment α-level discretization has been developed. This description enables prediction without the usually performed defuzzification and refuzzification of fuzzy data. The following types of fuzzy random processes are investigated: fuzzy-AR-processes, fuzzy-MA-processes, fuzzy-ARMA-processes and fuzzy-white-noise-processes. Two strategies for parameter estimation have been developed that are applicable for stationary and non-stationary fuzzy time series. After parameter estimation the underlying fuzzy stochastic process is known and can be used for forecasting.

The developed theory is demonstrated by way of examples among others the heavy goods vehicle traffic over a bridge is forecasted. Furthermore, on the basis of measured settlements over a period of four years the future settlements for the next three years are predicted with a h-step-forecast.