Long-term profile monitoring with multivariate functional data for application in structural health monitoring

P. Wittenberg[1], ***A. Mendler***[2], ***S. Knoth***[1], ***J. Gertheiss***[1]

[1]Department of Mathematics and Statistics, Helmut Schmidt University, Germany
[2]Department of Materials Engineering, Technical University of Munich, Germany

Structural Health Monitoring (SHM) is crucial in modern civil engineering, enabling the assessment of infrastructure integrity and health. However, environmental influences and measurement errors often obscure structural changes, making it challenging to detect anomalies. This paper presents a novel multivariate monitoring approach for SHM based on functional data analysis (FDA), extending a recently introduced framework of Wittenberg et al. (2025). By integrating supervised and unsupervised methods within a unified function-on-function regression framework, our approach effectively mitigates covariate-induced variations, enhancing the detection of structural changes in multivariate sensor data streams. This results in a comprehensive and robust method for SHM applications, capable of handling large, complex, and/or sparse sensor data.

Keywords: Functional Data Analysis, Multivariate Exponentially Moving Average control chart, Principal Component Analysis

Acknowledgements
This research paper out of the project 'SHM – Digitalisierung und Überwachung von Infrastrukturbauwerken' is funded by dtec.bw – Digitalization and Technology Research Center of the Bundeswehr, which we gratefully acknowledge. dtec.bw is funded by the European Union – NextGenerationEU.

References
[1] Wittenberg P, Neumann L, Mendler A, Gertheiss J. Covariate-adjusted functional data analysis for structural health monitoring. Data-Centric Engineering. 2025;6:e27. doi:10.1017/dce.2025.18