

ANALYSIS OF FRACTIONAL DYNAMICAL SYSTEMS USING RECURSIVE BAYESIAN ESTIMATION METHODS AND RESPONSE DATA

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Recibido: 14/10/2024 · Aceptado: 2/11/2024

Cómo citar: Erazo, K., Di Matteo, A., Spanos, P. D. (2024). Analysis of fictional dynamical systems using recursive Bayesian estimation methods and response data. *Ciencia, Ingenierías y Aplicaciones*, 7(2), 139-141. <https://doi.org/10.22206/cyap.2024.v7i2.3338>

Abstract

The research titled Analysis of fractional dynamical systems using recursive Bayesian estimation methods and response data was presented at the Engineering Mechanics Institute Conference and Probabilistic Mechanics & Reliability Conference (EMI/PMC 2024), University of Illinois Urbana-Champaign, Chicago, IL, May 28-31 2024, as part of the Minisymposium Computational methods for stochastic engineering dynamics.

Keywords: Fractional systems; Bayesian estimation; system identification; parameter estimation

Recursive Estimation of Fractional Systems

Recursive estimation methods integrate analytical models with noisy vibration data to infer the parameters and response of dynamical systems. The objective is to optimize the predicting capability of a model by minimizing (in some sense) modeling uncertainty and modeling errors (Lei et al, 2019). The inferred response and parameters are applied to structural condition/damage assessment and prediction, improvement of design methods, and structural control (Erazo and Nagarajaiah, 2018; Erazo

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et al., 2019; Erazo and Nagarajaiah, 2022). In this work the application of a class of time-domain recursive inverse methods in the context of structural systems comprising fractional derivative elements is studied. In contrast to classical linear systems, where stiffness and damping are independent structural characteristics, fractional-order elements influence both stiffness and damping simultaneously which allows to model the response and behavior of dynamical systems exhibiting strong memory characteristics more accurately. Engineering applications of systems exhibiting strong memory characteristics include damping and energy dissipation mechanisms, fluids sloshing, creep and relaxation, among others (Erazo et al., 2024). The recursive estimation methods studied use vibration data, typically in the form of noisy acceleration measurements, and combine the data with a numerical model of the system of interest in a probabilistic setting. The use of response measurements allows solving the inverse problem of parameter estimation, response estimation, and/or input estimation, and reduces inherent modeling errors that result from the analytical and numerical models employed.

The effectiveness of recursive nonlinear filtering-based parameter estimation methods in the identification of structural fractional systems is assessed (Erazo and Nagarajaiah, 2017). The study includes results for multiple degrees-of-freedom systems and nonlinear-hysteretic systems. Further, an experimental analysis is conducted to assess the effectiveness of the methods using real data. The experimental system consists of a frame structure equipped with a tuned liquid column damper device applied for vibration suppression/control. The system exhibits fractional calculus features due to fluid sloshing in the device. The use of a traditional nonlinear sloshing model, as well as of a fractional model, is explored.

The advantages and limitations of the proposed framework are examined using pertinent numerical simulations and the experimental data. The analyses are performed under several conditions, including various measurement noise levels, known and uncertain inputs (input-output and output-only implementations), different kinds of inputs, and various kinds of measurements.

References

- Erazo, K., Di Matteo, A., and Spanos, P. (2024). Parameter estimation of stochastic fractional dynamic systems using nonlinear bayesian filtering system identification methods. *Journal of Engineering Mechanics*, 150(2), 04023117.
- Erazo, K., and Nagarajaiah, S. (2017). An offline approach for output-only Bayesian identification of stochastic nonlinear systems using unscented Kalman filtering. *Journal of Sound and Vibration*, 397, 222-240.
- Erazo, K., and Nagarajaiah, S. (2018). Bayesian structural identification of a hysteretic negative stiffness earthquake protection system using unscented Kalman filtering. *Structural control and health monitoring*, 25(9), e2203.
- Erazo, K., and Nagarajaiah, S. (2022). Structural Health Monitoring of Civil Infrastructure Using Applied Recursive Bayesian Estimation Methods. In *Recent Developments in Structural Health Monitoring and Assessment—Opportunities and Challenges: Bridges, Buildings and Other Infrastructures*, 171-195.
- Erazo, K., Sen, D., Nagarajaiah, S., and Sun, L. (2019). Vibration-based structural health monitoring under changing environmental conditions using Kalman filtering. *Mechanical systems and signal processing*, 117, 1-15.
- Lei, Y., Xia, D., Erazo, K., and Nagarajaiah, S. (2019). A novel unscented Kalman filter for recursive state-input-system identification of nonlinear systems. *Mechanical Systems and Signal Processing*, 127, 120-135.