

PARAMETER ESTIMATION IN A NONLINEAR MECHANICAL SYSTEM USING AN ADAPTIVE CUBATURE KALMAN FILTER

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ABSTRACT

Many industrial systems are subject to varying operating conditions and frequent start and stop cycles, leading to unpredictable failures. Health monitoring of complex systems relies on the accurate estimation of their unknown parameters to predict the response. Tracking the rate of change in the parameters and responses helps to identify damage and to prevent catastrophic failures before they occur thereby extending the operational life. Some parameters, such as damping or boundary conditions, are critical for system modelling and health monitoring, but they may be difficult or impossible to measure directly, especially for a non-linear system. Developing a parametric model and using data-driven methods open an avenue to identify these quantities of interest using sensor data.

In this study, we use an adaptive Cubature Kalman Filter (CKF), which is a derivative-free type of Kalman filtering to estimate the unknown and unmeasurable parameters of an experimental cantilever beam setup with two perpendicular springs at its free end. These springs are designed to impose a geometrical nonlinearity on the system [1]. The CKF is based on the approximation of the probability function by a set of sigma points obtained by the cubature rule [2]. This filter performs well on high-dimensional systems and offers lower computational cost than the unscented Kalman filter. The adaptive CKF is able to predict the linear and cubic stiffness of the springs at the end of the beam using both simulated and experimental data from the test rig. The adaptivity of the filter also helps to quantify the modelling and measurement errors within the identification process.

In the next step, this study will be extended to rotor dynamics, firstly by estimating the bearing coefficients, i.e., stiffness and damping, of a vertical axis rotating machine. Secondly, failure cases such as the estimation of an unbalanced mass or a misalignment of the bearing will be studied to create a digital twin of the rotating machine.

REFERENCES

- [1] SHAW, Alexander D., HILL, Tom L., NEILD, Simon A., *et al.* Periodic responses of a structure with 3: 1 internal resonance. *Mechanical Systems and Signal Processing*, 2016, vol. 81, p. 19-34.
- [2] ARASARATNAM, Ienkaran et HAYKIN, Simon. Cubature kalman filters. *IEEE Transactions on automatic control*, 2009, vol. 54, no 6, p. 1254-1269.