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STATE SPACE MODELING AND ESTIMATION OF FLEXIBLE STRUCTURE USING THE THEORY OF FUNCTIONAL CONNECTIONS

Abstract

In this work we present a method to model the dynamics of a continuous structure based on measurements taken at discrete points. Both the measurements and the model that describes the structure can be affected by uncertainty. The purpose of the developed method is to estimate the position and the velocity of any point of the physical domain relying on a limited number of measurements while filtering out the noise. To this aim, the well-assessed Kalman filter is used in synergy with the recently developed Theory of Functional Connections (TFC). This is a mathematical framework to perform functional interpolation with applications in many fields being currently discovered and investigated.

Initially, an algorithm for the solution of the corresponding static problem was developed based on the TFC; the results of the tests were promising and the approach presented in this work constitutes an effort to extend the idea to the dynamic case.

In the proposed method, the continuous structure is approximated by the TFC constrained expression, while the system state variables are defined as the coefficients used to represent the free function in a basis of orthogonal polynomials. This leads to a system that, despite being continuous and thus formed of an infinite number of material points, is modeled using a finite number of state variables allowing for the use of Kalman filter to deal with the uncertainties intrinsic in both the modeling and measurements. This is accomplished by exploiting the original structure model Differential Equation(s) to obtain a process model for the filter and using the constrained expression itself as the measurement model. Then the Kalman filter algorithm is applied and the *a posteriori* estimates of the state variables (that is the free function coefficients) can be used to build the TFC expression that approximates the instantaneous shape of the structure, thus enabling the evaluation of the displacement at any point of the domain. The power of the proposed method is twofold. First, an estimate of the displacements of all the points is obtained based on a limited number of noisy measurements. Second, the relation between discrete measurements and continuous displacement field always accounts for the real physics of the problem.