Abstract

This thesis attempts to investigate efficient techniques for modeling and estimation of Distributed Parameter Systems (DPS) with applications to process monitoring and fault identification. DPS appear in a wide range of practical systems which are mathematically modeled using Partial Differential Equations (PDE). As a first step for designing an estimator for a PDE, a reduced-order model of the PDE needs to be developed using spatial basis function approximations. The order of such a model or the related accuracy is critically dependent on the choice of the basis functions and the type of the PDE. Consequently, the principal challenge for designing an estimator for DPS is to formulate a general approximate model for the PDEs suitable for estimation. The model should automatically choose the basis so as to make the approximate system sufficiently low order and accurate and hence suitable for online implementation.

The major contribution of this thesis lies in the development of this basic framework for estimation of the distributed profile of states of a DPS. The referred framework uses a Hybrid Basis Approximation Method (HBAM) which is capable of choosing appropriate basis functions online by using a monitor function. This type of modeling can provide low order yet sufficiently accurate dynamic model for PDEs with sharp spatial gradient. For other PDEs with smooth spatial gradient, modeling with continuous basis is shown to provide better results. This model is used in conjunction with states estimators like Kalman Filter, Extended Kalman Filter etc. to dynamically estimate distributed profile of the states illustrated by case studies. A joint input and state estimation technique has been proposed as well to simultaneously predict the unknown boundary inputs for the DPS. The technique has been validated for an inverse heat conduction problem, common in many popular applications.

The HBAM technique has been applied for modeling an actual industrial example, static sintering process. The location of the fire-line in the sinter pot is estimated based on temperature measurements at two different heights of the pallet. The dynamic location of the fire-line is essential for process control, monitoring and fault detection which can be achieved as an application of this work. Finally the proposed framework has been used to model the leak in a tubular counter-flow type heat exchanger. The proposed method can estimate unknown mass flow rate input in the estimator from temperature measurements. Additionally the estimator algorithm can successfully detect leak and identify leak location in a heat exchanger which allows swift remedial action. The efficacy of the HBAM and the framework for estimation is demonstrated through several practical industrial examples. The theoretical analysis and the furnished applications raise the potential for monitoring and control of a wide variety of industrial processes involving DPS.

Keywords: Distributed Parameter System, Partial Differential Equation, Modeling, Basis Function, State Estimation, Input Estimation, Sintering Process, Inverse Heat Conduction Problem, Heat Exchanger, Leak Detection.