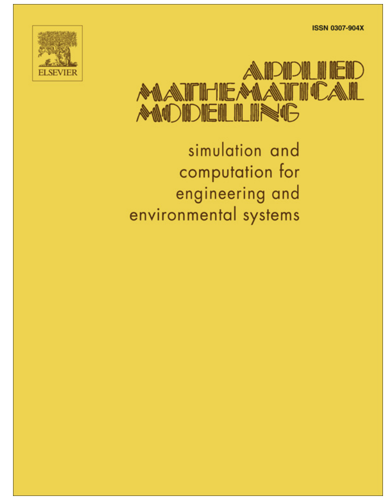
Accepted Manuscript



State-space estimation with a Bayesian filter in a coupled PDE system for transient gas flows

Ferdinand E. Uilhoorn

PII: S0307-904X(14)00341-2
DOI: http://dx.doi.org/10.1016/j.apm.2014.06.021
Reference: APM 10069

To appear in: *Appl. Math. Modelling*

Received Date: 16 July 2013
Revised Date: 21 May 2014
Accepted Date: 30 June 2014

Please cite this article as: F.E. Uilhoorn, State-space estimation with a Bayesian filter in a coupled PDE system for transient gas flows, *Appl. Math. Modelling* (2014), doi: http://dx.doi.org/10.1016/j.apm.2014.06.021

State-space estimation with a Bayesian filter in a coupled PDE system for transient gas flows

Ferdinand E. Uilhoorn[1]

Gas Engineering Division, Department of Environmental Engineering, Warsaw University of Technology, Nowowiejska 20, 00-653 Warsaw, Poland

Abstract

The accuracy of the first-principle models describing the evolution of gas dynamics in pipelines is sometimes limited by the lack of understanding of the gas transport phenomena. In this paper, a stochastic filtering approach is proposed based on a sequential Monte Carlo method to provide real-time estimates of the state in gas pipelines. After constructing a state-space model of the compressible single-phase flow based on the laws of conservation of mass and momentum, the optimal sequential importance resampling filter (SIR) is implemented. The state variables are updated with simulated measurements. The two-step Lax-Wendroff method is used for the discretization of the partial differential equations describing the gas model in both space and time to obtain finite-dimensional discrete-time state-space representations. The system states are then combined into an augmented state vector. The resulting nonlinear state-space model is used for the design of the particle filter that provides real-time estimations of the system states. Simulation results for a coupled PDE system describing an unsteady isothermal gas flow demonstrate the effectiveness of the proposed method. A sensitivity analysis is conducted to examine the performance of the filter for different model and observation error covariances and observation intervals.

KEY WORDS: Bayesian filtering; Monte Carlo methods; Particle filter; Unsteady compressible gas flow, Nonlinear/non-Gaussian, two-step Lax-Wendroff

1. Introduction

Mathematical modelling of compressible unsteady natural gas flows is important in the design of compressors and heat exchangers, orifice plates and sonic nozzle metering, conversion of gas volumes to the reference state, estimation of the linepack [1], hydrate prevention [2, 3] and leak detection [4, 5]. Issa and Spalding [6], Deen and Reintsema [7] and Thorley and Tiley [8] developed the basic equations for a one-dimensional, unsteady, compressible single-phase flow, including the effects of wall friction and heat transfer. These models aim to predict accurately, the measurable quantities of pressure, temperature and mass flow in the pipeline. The uncertainties related to the model parameters, initial and boundary conditions cause model errors that can propagate in time. The model noise represents for example, diameter or roughness changes, fluctuations in gas composition, unknown ambient temperature changes, changes in soil moisture properties for buried pipelines, liquid dropout in a wet gas and so on. As a result, the final predictions can significantly differ from the reality. For this reason, a suitable approach of simulating gas dynamics in pipelines is to consider them as realizations of a stochastic process and find the most probable one or even the full probability distribution of the state. The

[1] Tel.: +48226213609; fax: +4822 825 29 92
E-mail address: frits.uilhoorn@is.pw.edu.pl