Dynamic Modelling of a Falling-film Evaporator for Model Predictive Control

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Abstract

Fundamentally this thesis provides a study into dynamic modelling of a pilot-scale falling-film evaporator. Its main aim, however, is to research and demonstrate artificial neural network (ANN) modelling for model predictive control as applied to an evaporator system.

As a prerequisite to testing an advanced control strategy such as model predictive control one must have available a suitable dynamic simulation of the process. To this end the thesis initially presents the formulation of a dynamic model of the evaporator system developed from first-principles.

A novel approach to developing a dynamic ANN representation of a process is presented and applied to the evaporator. This approach incorporates prior knowledge of the system into the network topology to attain a model with a flexible, modular structure. A dynamic, recurrent training methodology is devised to enable the ANN model to predict over a future horizon of arbitrary length.

The performance of the modular ANN model is compared with a linear model of a similar form identified through conventional linear regression methods. It was found that the nonlinear ANN model and subsequent nonlinear MPC scheme exhibited no improvement in performance to that of their linear counterparts.

Errata

p. 31	paragraph 4, line 1 should read:	"...with an evaporation rate..."
p. 42	paragraph 4, line 2 should read:	"...shows how the energy..."
p. 46	paragraph 1, line 1 should read:	"...A_l is a function of L..."
p. 47	paragraph 7, line 2 should include:	"...l_e/d..." and not "...L_e/d..."
p. 83	paragraph 4, line 2 should read:	"...by the model as a function of..."
p. 104	paragraph 1, line 1 should read:	"...then the neuron will turn on..."
p. 105	paragraph 2, line 2 should read: paragraph 3, line 2 should read:	"...are adapted it is said that..." "...on opposite sides of a hyperplane..."
p. 118	paragraph 3, line 5 should read:	"...a number of times..."
p. 157	paragraph 2, line 5 should read:	"...foolhardy..."
p. 166	paragraph 4, line 4 should read:	"...was selected for study..."
p. 168	paragraph 2, line 1 should read:	"...of the effect requires four input variables..."
p. 169	paragraph 8, line 2 should read:	"...but this was considered to short."
p. 190	paragraph 1, line 3 should read:	"...output of neuron 2 has an inverse..."
p. 199	paragraph 2, line 7 should read:	"...individual errors are not as good..."
p. 231	paragraph 1, line 3 should read:	"...occur at a time of 1 minute and eight minutes on the plots."
p. 234	Figure 8-6:	in the legend the "PI-control" and "NN-MPC" labels have been interchanged.

Thesis Contribution

This thesis has made the following contributions:

Analytical modelling

1. The development of an analytically-derived, dynamic model of a falling-film evaporator pilot-plant which is an extension of earlier modelling work.

   The major extensions to the evaporator model include:

   - the re-formulating of the model for a feedforward configuration,
   - the deriving of equations for the preheater system,
   - the deriving of equations for the venturi condenser sub-systems, and
   - the inclusion of an additional product temperature state variable.

2. The combining of the analytical sub-models for three evaporation effects and the additional sub-systems to describe the complete evaporator system.
3. The validation of the complete analytical model against data from the actual plant.

Artificial neural networks

4. The conception of a modular, artificial neural network modelling approach for the development of models to be used within a predictive control strategy.
5. The demonstration of neural network structure selection based upon prior knowledge of the system to create locally-connected, modular models.
6. The application of a dynamic, recurrent training methodology combining backpropagation through time and the Levenberg-Marquardt optimisation method to train the neural networks.
7. The comparison of a modular, artificial neural network model and an equivalent linear model identified through conventional regression techniques.

Model Predictive Control

8. The demonstration of the modular artificial neural network within a model predictive control strategy applied to the evaporator simulation.

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Table of Contents