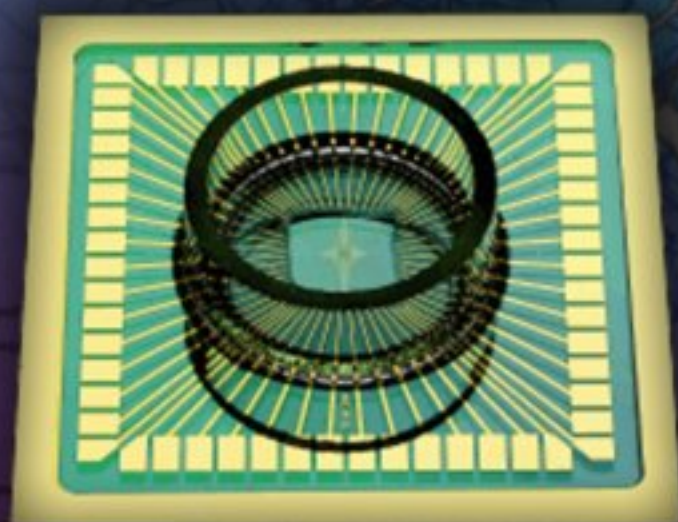


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# **SENSORS** **&** **TRANSDUCERS**

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## **Soft Sensors and Artificial Neural Networks**

International Frequency Sensor Association Publishing



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## The Seventh International Conference on Networking and Services

# ICNS 2011

May 22-27, 2011 - Venice, Italy



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Submission (full paper)	January 10, 2011
Notification	February 20, 2011
Registration	March 5, 2011
Camera ready	March 20, 2011

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- ENCOT: Emerging Network Communications and Technologies
- COMAN: Network Control and Management
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- Biological technologies
- Biomanufacturing

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Submission (full paper)	January 10, 2011
Notification	February 20, 2011
Registration	March 5, 2011
Camera ready	March 20, 2011

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## The Sixth International Conference on Systems

# ICONS 2011

January 23-28, 2011 - St. Maarten,  
The Netherlands Antilles



### Important deadlines:

Submission (full paper)	September 25, 2010
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Registration	November 5, 2010
Camera ready	November 5, 2010

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- Application-oriented systems [content, eHealth, radar, financial, vehicular, etc.]
- Safety in industrial systems
- Complex Systems

## **Control System Design for Cylindrical Tank Process Using Neural Model Predictive Control Technique**

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**Abstract:** Chemical manufacturing and process industry requires innovative technologies for process identification. This paper deals with model identification and control of cylindrical process. Model identification of the process was done using ARMAX technique. A neural model predictive controller was designed for the identified model. The performance of the controllers was evaluated using MATLAB software. The performance of NMPC controller was compared with Smith Predictor controller and IMC controller based on rise time, settling time, overshoot and ISE and it was found that the NMPC controller is better suited for this process. *Copyright © 2010 IFSA.*

**Keywords:** Cylindrical process, Model identification, Neural model, ARMAX.

---

### **1. Introduction**

Process control is of vital importance in the operation of chemical, pharmaceutical, biochemical, power plant, semiconductor, paper and bleach processes. Strict environmental regulations and growing concern for prevention of pollution have recently increased its importance. In industrial processes, the drive to reduce operating costs and develop new markets has frequently emphasized improvements in product quality, better use of energy resources and reduced environmental emissions. Madhavasarma et al [1-5] have designed an instrumentation scheme for monitoring and controlling water in a non linear spherical tank process. Diezo et al [6] have developed hardware circuit for conductivity measurements of KCL solution and have converted conductivity into continuous voltage signal for offline analysis. Diego et al [7] have developed experimental model for the measurements of conductivity data at constant temperature on specific concentrated systems in industrial process. Model

predictive control depicts range of control methods, which makes an explicit use of a model of the process to calculate the manipulated variable by minimizing an objective function. Various Model predictive control (MPC) algorithms differ almost only in the model used to represent the process and the noise and the objective function to be minimized. In the case of linear MPC, a characteristic system matrix is found using step or impulse signals [8]. However, most of the chemical process exhibits nonlinearity and these control loop are subjected to changes in set point according to demand and occurrence of various disturbances is unavoidable. In addition, any unit operation capable of manufacturing or refining a product in a process industry can not do so with only a single control loop. In fact, each unit operation typically requires control over an at least two variables. Henson et al. [9] have developed an adaptive nonlinear control strategy for a bench scale pH neutralization system. They have obtained the adaptive nonlinear control strategy by augmenting the non-adaptive controller with an indirect parameter estimation scheme, which accounts for unmeasured buffering changes. Gustafsson et al. [10] have explained the various methods used for the treatment of continuous control of pH in process streams. They have shown that use of a proper nonlinear process model for feedback control is essential to eliminate the bias of the oscillations and to result in an average pH close to the set point. They have also discussed the practical issues in the implementation of linear and nonlinear self-tuning control of pH. Vores has [11] discussed on adaptive feed forward control of Hammerstein non-linear systems where Hammerstein system and its identification method is clearly explained. Kalafatis et al. [12] have implemented feed forward-feedback control of pH process using linearization by output transformation method. The present work aims at identification of cylindrical tank model and design of neural based control algorithm to optimize the controller performance using MAT Lab software.

## 2. Experimental Setup

The photographic view of the experimental setup for conductivity measurement is shown in the Fig. 1. A concentrated tracer solution and fresh water are fed to a 20 liter cylindrical tank through two Gallen Kamp rotameters. The conductivity is monitored at the outlet using online Honeywell conductivity sensor. The cylindrical tank process is divided into three levels (L1, L2, and L3) longitudinally and various transportation lag is realized in each region using valves v4, v5 and v6. The sensor output is interfaced to a PC using real time data acquisition card from M/S AD Instruments.



**Fig. 1.** Photograph showing the experimental setup for conductivity measurement.



### 3. Model Identification

Consider a linear system as given below in equation 1

$$y(t) = G(q)u(t) + v(t), \quad (1)$$

where  $u(t), e(t), y(t)$  are input, output, error signals respectively here  $G(q)$  represent the Transfer function of the system,  $v(t)$  represent the white noise. The ARMAX Parametric Model is given in equation 2 and 2a

$$A(q)y(t) = B(q)u(t - nk) + C(q)e(t), \quad (2)$$

where

$$\begin{aligned} A(q) &= 1 + a_1 q^{-1} + \dots + a_{na} q^{-na} \\ B(q) &= 1 + b_1 q^{-1} + \dots + b_{nb} q^{-nb} \\ C(q) &= 1 + c_1 q^{-1} + c_2 q^{-2} + \dots + c_{nk} q^{-nk}, \end{aligned} \quad (2a)$$

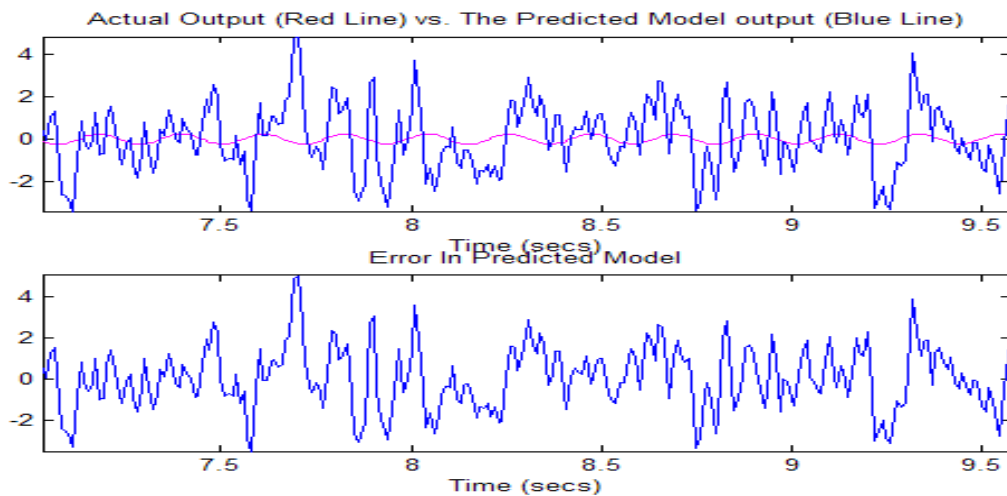
where  $na, nb$  represent the order of the polynomial,  $nk$  represent the time delay between the input and output respectively. The ARMAX parametric model for the system is represented below discrete-time IDPOLY model is given equation 3, 4 and 5.

$$A(q)y(t) = B(q)u(t) + C(q)e(t) \quad (3)$$

$$B(q) = -0.01739 + 0.03479 q^{-1} - 0.01739 q^{-2} \quad (4)$$

$$C(q) = 1 - 1.749 q^{-1} + 1.018 q^{-2} - 0.1453 q^{-3} \quad (5)$$

Here the order of the polynomial is three and the time delay between the input and output of the system is three. The actual output of the system and predicted model output is shown in Fig. 2.



**Fig. 2.** Actual and Predicted model output and Error in predicted model.

#### 4. Design of Neural Model Predictive Controller

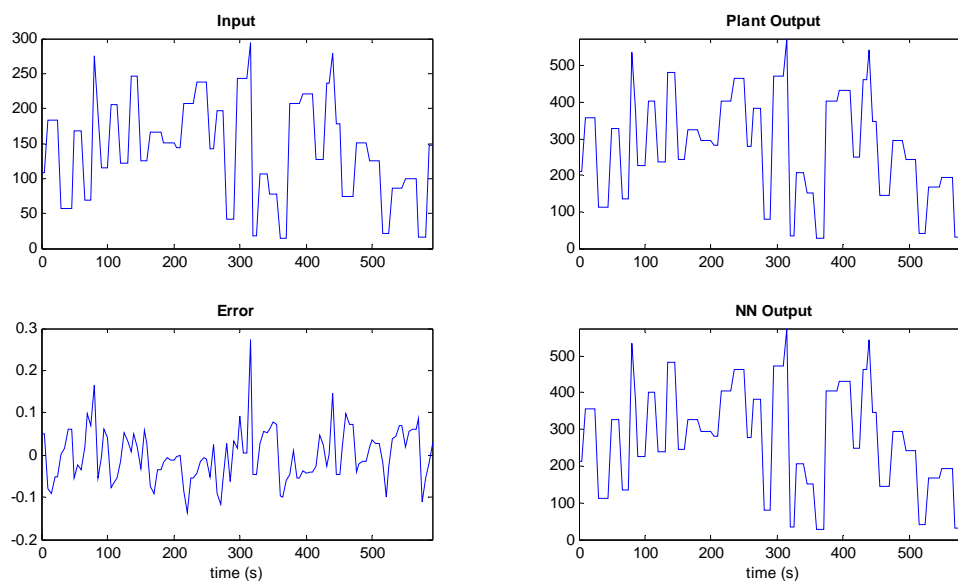
Neural model predictive control was designed using neural network toolbox. Data collected from the experimental test was used to train the network. The convergence criteria were selected as  $10^{-3}$ , and this was achieved in 29 epochs. The back propagation through time (BPTT) algorithm was used for training the network. Neural model predictive control was designed for the prediction horizon 6 and control horizon 2 using trained input-output data. Performance of the controller was evaluated for the step change in set point.

#### 5. Result Analysis

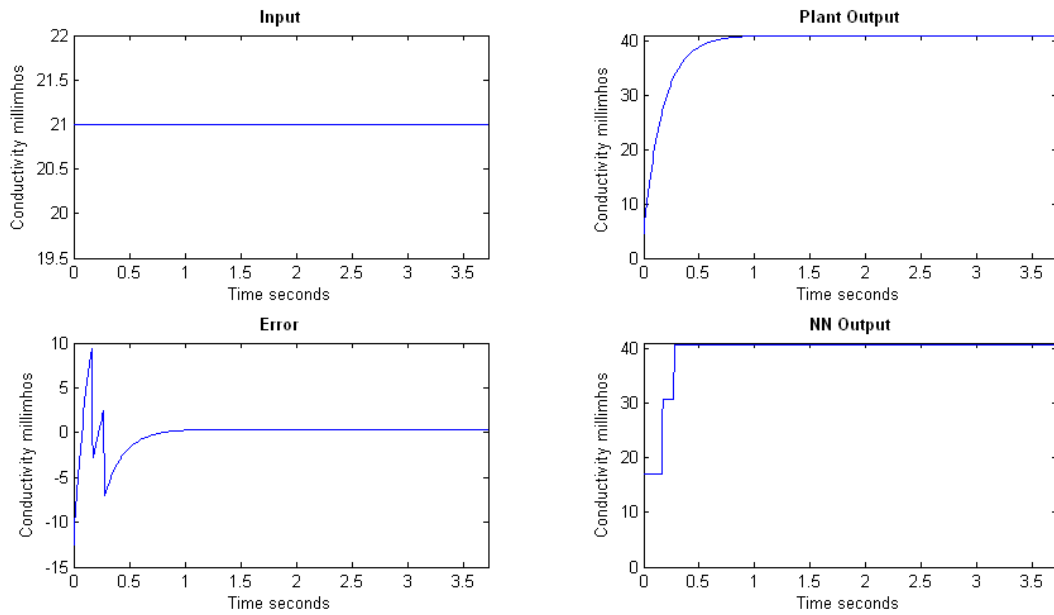
To evaluate closed loop performance of the neural controller for the cylindrical tank process a step change of 40 units in set point was introduced. The poorly tuned process performances and optimum performances are shown in Figs. 3 and 4 respectively. The results are compared with well tuned IMC, Smith predictor controllers are shown in Fig. 5. The NMPC scheme was found to exhibit lesser oscillation than conventional controlled system. The mean square error for validation are calculated and shown in Table 1. The output control performance was measured by computing ISE values and by determining the rise time, settling time and overshoot. The time domain performance specification and the ISE values for servo and regulatory response of the neural model predictive controller are given in Table 2.

#### 6. Conclusions

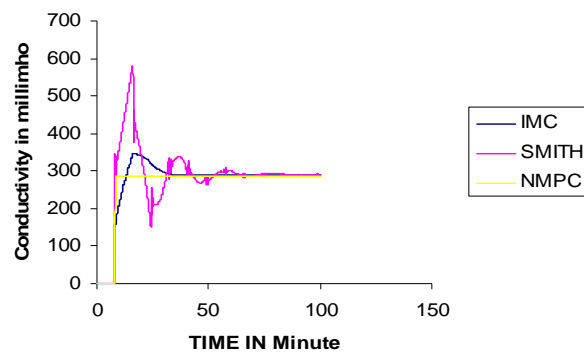
The results given in Table 2 emphasize that the Neural Model Predictive controller shows a minimum dynamic response time than the conventional controllers. While conventional controllers reaches the set point smoothly. It is evident from Table 2 that neural model predictive controller offers best time domain characteristics such as rise time, settling time, overshoot, for the cylindrical tank process.



**Fig. 3.** Validation data for poorly tuned controlled response.



**Fig. 4.** Validation of the NN model with process for optimum alpha value 0.01 for Cylindrical process.



**Fig. 5.** Comparison of servo response of the controllers for the cylindrical process.

**Table 1.** Selection of optimum alpha value.

S.No	Alpha	MSE
1	0.01	25527
2	0.02	25898

**Table 2.** Comparison of performance of controllers.

Controllers		SMITH	IMC	NMPC
Cylindrical Process	Settling time in seconds	160	250	7
	Rise time in seconds	60	100	5
	Peak over shoot (%)	34.3	16.2	0
	ISE	0.7493	0.0123	0.0054378



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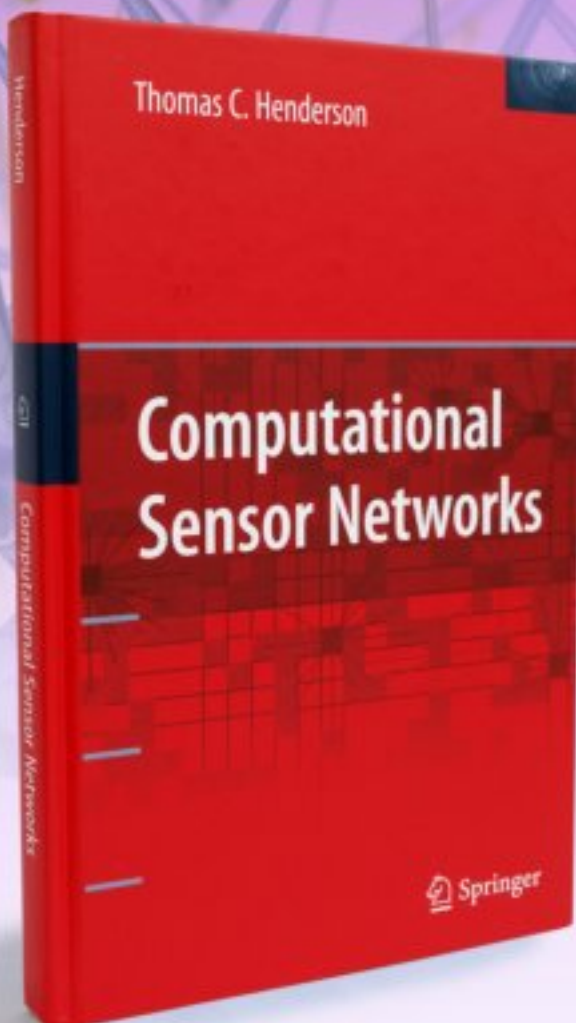
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