A METHODOLOGY FOR DESIGNING CONTROLLERS FOR INDUSTRIAL SYSTEMS BASED ON NONLINEAR SEPARATION MODEL AND CONTROL

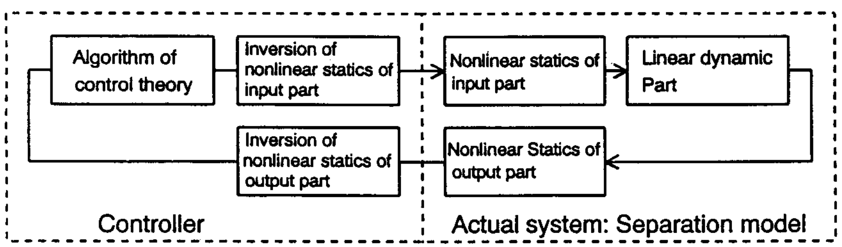
Masatoshi NAKAMURA (Saga University, Japan)

○ Controller Design for Industrial Nonlinear Dynamical Systems
- Nonlinear Separation Model and Control
- Reduction the Gaps between Theory and Practice

CONTENTS

NONLINEAR SEPARATION MODEL AND CONTROL

○ Nonlinear Statics and Linear Dynamics



○ Controller Design
- Mirror Image of the Separated Model
- Nonlinear Statics – Inversion
- Linear Dynamics – Linear Control

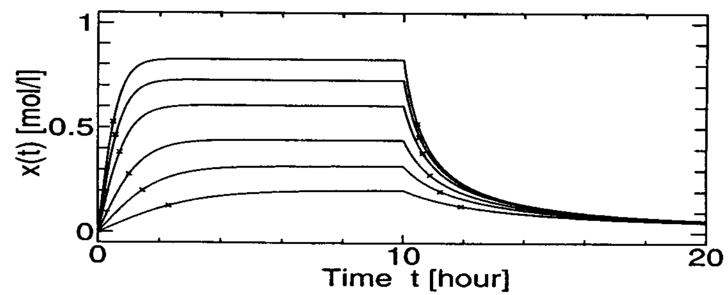
NONLINEAR CHEMICAL REACTOR

○ Control Object

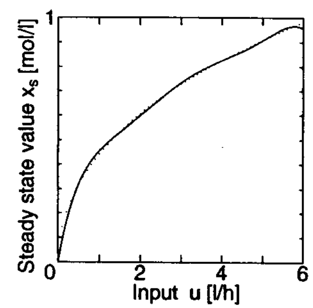
$$\frac{dx(t)}{dt} = -K_r(x(t))^2 + \frac{1}{V}(D_c - x(t))u(t)$$

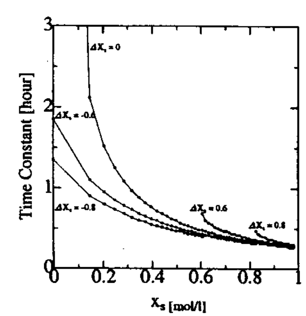
x: Output Concentration, u: Inflow Rate
K_r: Reaction Speed, V: Reactor Capacitor
D_c: Input Concentration
- Follow the Output Concentration x to a Desired Value

○ Step Response for u(0.2, 0.5, 1, 2, 3, 4)



○ Nonlinear Separation Model





$$G_n(s) = \frac{X(s)}{U(s)} = \frac{X_s(s)}{U(s)}\frac{X(s)}{X_s(s)} = \frac{K(u)}{1+T(x_s, \Delta x_s)s}$$

- Nonlinear Statics

$$x_s = \Sigma_{i=0}^{6} a_i (u)^i$$

- Dynamics

$$G_d(s) = \frac{X(s)}{X_s(s)} = \frac{1}{1+T(x_s, \Delta x_s)s}$$

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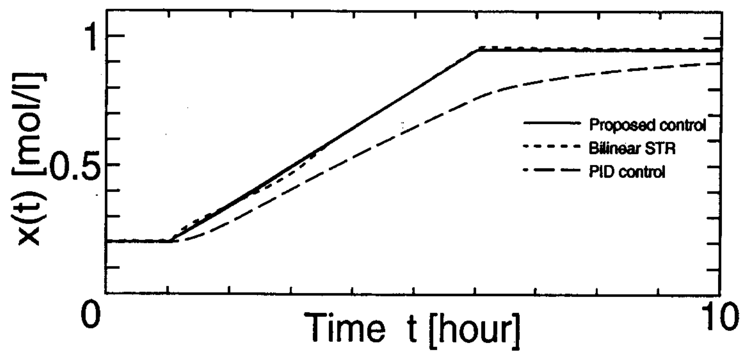
○ Controller Design

- Inversion of Nonlinear Statics : $u = \Sigma_{i=0}^{6} b_i (x_s)^i$
- Inverse Dynamics: $G_d^{-1}(s) = 1 + T(x_d, \Delta x_d)s$

○ Simulation Results



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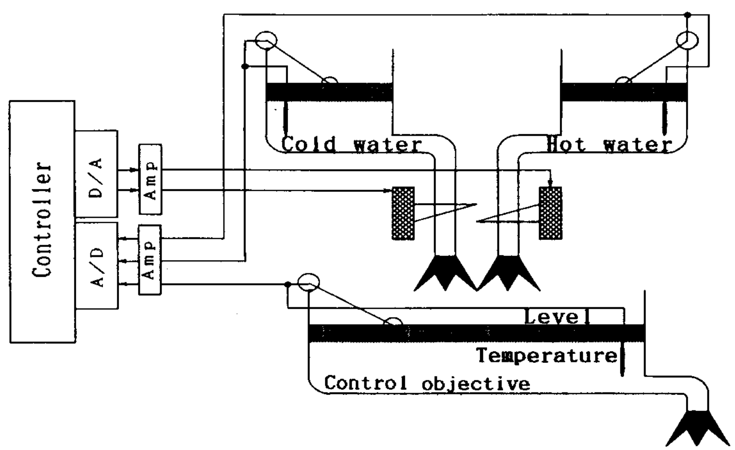
TANKED WATER SYSTEM



○ Control Objective

Maintain Level and Temperature of Lower Tanked Water at Respective Desired Values

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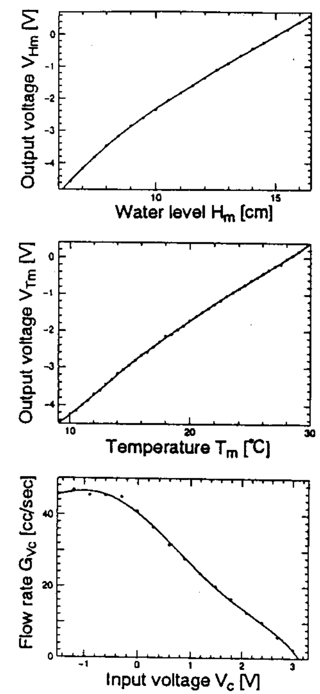

○ Nonlinear Separation Model

- Level Meter

  Float-Potentio

  $V_{H_m} = 1.66 \times 10^{-3}(H_m)^3 - 7.22 \times 10^{-2}(H_m)^2 + 1.48 H_m - 11.5.$

- Thermometer

  $V_{T_m} = 9.04 \times 10^{-6}(T_m)^3 - 3.01 \times 10^{-3}(T_m)^2 + 3.40 \times 10^{-1} T_m - 7.37.$

- Actuator

  DC Motor-Valve

  $G_{V_c}(V_c, H_c^0) = -1.49 \times 10^{-1}(V_c)^5 + 3.50 \times 10^{-1}(V_c)^4 + 1.60(V_c)^3 - 4.35(V_c)^2 - 11.4V_c + 40.7,$

  $G_{H_c}(V_c^0, H_c) = -1.68 \times 10^{-4}(H_c)^5 + 3.95 \times 10^{-3}(H_c)^4 + 3.53 \times 10^{-2}(H_c)^3 - 1.69(H_c)^2 + 16.6H_c - 35.7$

$\rightarrow$ Linear Dynamical System

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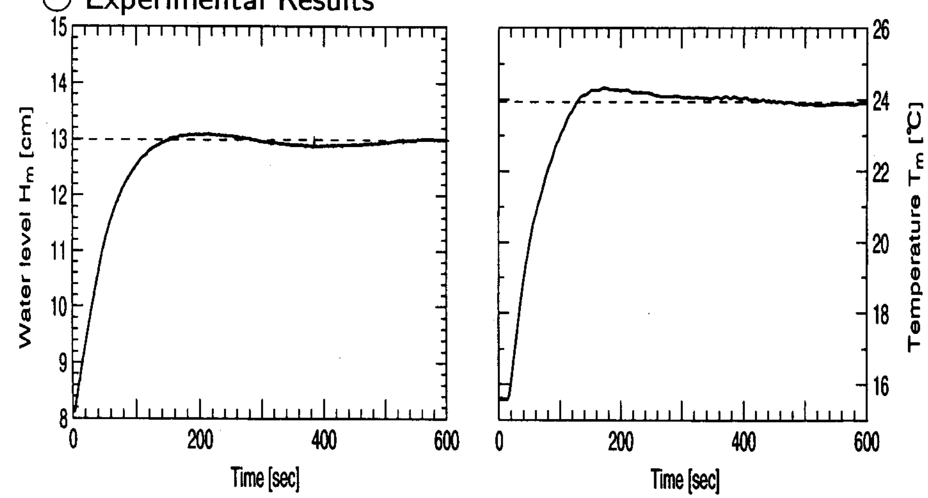
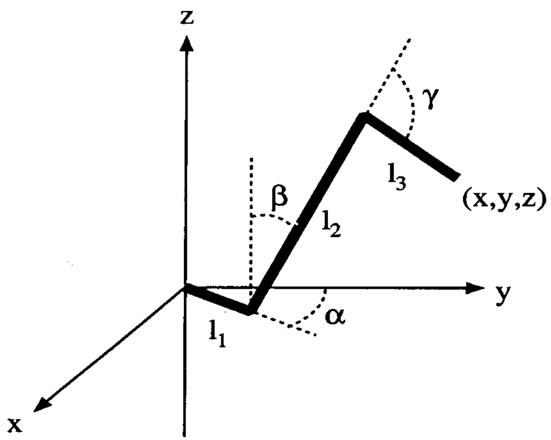
○ Controller Design

- Inversion of Nonlinear Statics for Detectors and Actuator
- A Delay Compensation Method

○ Experimental Results

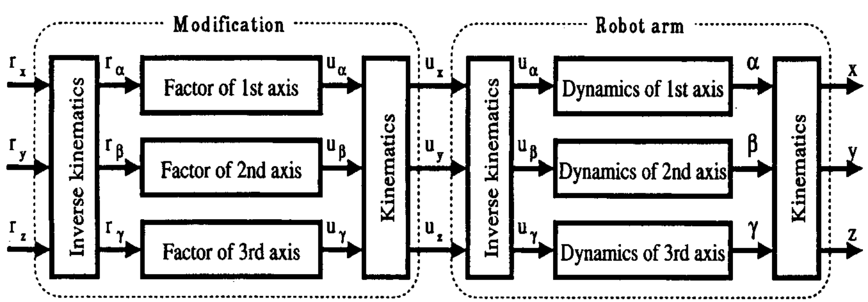


ROBOT ARM



○ Control Objective
Accurate Contour Trajectory of Articulated Robot Arm

○ Nonlinear Separation Model

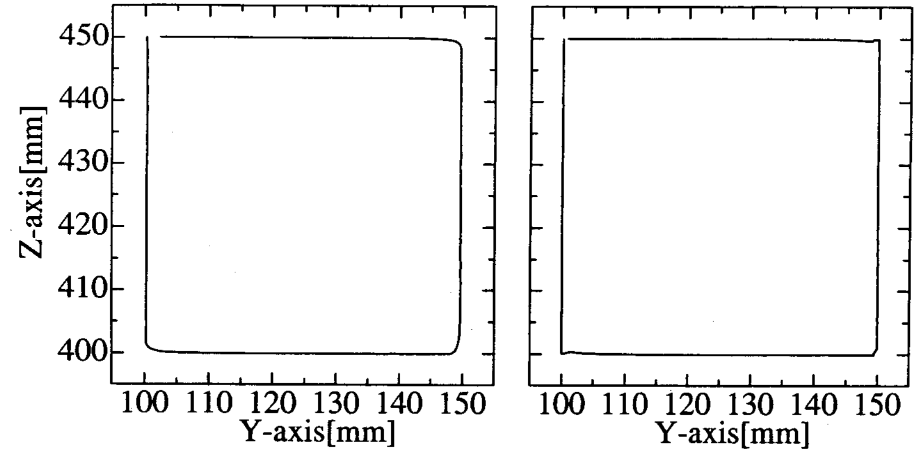


- Dynamics of Each Link

$$G(s) = \frac{K_p K_v}{s^2 + K_v s + K_p K_v}$$

○ Controller Design
- Nonlinear Statics – Kinematics, Inverse Kinematics
- Linear Dynamics – Modified Taught Data Method

○ Experimental Results



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