Indian Institute of Technology Bombay

Hardware Interfacing & Control

Prof. P. S. V. Nataraj
PC Based Interface

Using Custom Hardware interface

Microcontroller based custom Hardware

Serial Port

USB

Encoder

IIT Bombay
DC motor Control Kit

Developed By
IIT Bombay
DC Motor Control

Controller → Motor Driver → Encoder

Speed Set point

Speed Feedback
DC motor Control Kit

Microcontroller & Motor Driver Board

Encoder

Variable Voltage to Motor

Rotary Encoder feedback

Serial Port

USB

Set point

Speed RPM

Current RPM

Feedback

IIT Bombay
DC motor Control Kit

Training Modules
- Modules for Speed & Position control
- System Identification
- Traditional Control using P PI PID
- Neural Networks
- Deep Learning
- MPC
- Robust Control
DC motor Control Kit

Used for class room teaching over 4 years in IIT

Low Cost

USB Connectivity – Plug & Play

Creates real world plant experience on your desktop

Interactive frontend Software modules

Complete Lab Development Package for Academics

Open communication command set

IIT Bombay
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DC Motor control using MATLAB/SIMULINK
Outline

• Experiment No- 1
  • Validation of motor model for speed control

• Experiment No-2
  • PI Control Gains for Motor speed control
Experiment No-1
Validation of motor model for speed control
Procedure

• Set \( ts=0.015 \)
• Run the matlab simulink model
• To stop the motor press the reset button on the DC motor kit.
FOPTD

• The First-order Plus Time Delay (FOPTD) model is given by

\[ G(s) = \frac{\Delta Y(s)}{\Delta U(s)} = \frac{K e^{-t_d s}}{\tau s + 1} \]

gain \( K \), time constant \( \tau \) and dead time \( t_d \)
Apply two-point method for system

• $t_{63.2}$ = Time required for the output to reach 63.2% of the steady-state value
• $t_{28.3}$ = Time required for the output to reach 28.3% of the steady-state value.
• $K = \frac{\text{Difference in two steady states of output}}{\text{Difference in two steady states of input}}$
• $\tau = 1.5(t_{63.2} - t_{28.3})$
• $t_d = t_{63.2} - \tau$
Sample values

- $t_{63.2} = 0.45 \text{ sec}$
- $t_{28.3} = 0.33 \text{ sec}$
- $\Delta u(t) = 20 \text{ PWM units}$
- $\Delta y(t) = 359 \text{ RPM}$
- Using the two-point method

\[
K = 17.95 \\
\tau = 0.18 \text{ sec} \\
L = 0.12 \text{sec}
\]
Transfer function

\[ G(s) = \frac{\Delta Y(S)}{\Delta U(S)} = \frac{17.95 e^{-0.12s}}{0.18s + 1} \]
Output response

• In the open loop, the plant is brought to equilibrium by applying a step of 150 PWM units.
• The corresponding speed is around 2000 RPM
• After the motor speed settles, the PWM input is instantaneously changed to 170.
• As a result, the speed increases to around 2400 RPM.
Output vs Input
Experiment No-2
PI Control Gains for Motor speed control
### Ziegler-Nichols Rule for Tuning PID Controllers

<table>
<thead>
<tr>
<th>Type of controller</th>
<th>$K_c$</th>
<th>$T_i$</th>
<th>$T_d$</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>$1/RL$</td>
<td>$\infty$</td>
<td>0</td>
</tr>
<tr>
<td>PI</td>
<td>$0.9/RL$</td>
<td>3L</td>
<td>0</td>
</tr>
<tr>
<td>PID</td>
<td>$1.2/RL$</td>
<td>2L</td>
<td>0.5L</td>
</tr>
</tbody>
</table>
Calculations

- Compute the controller parameters as follows:

\[ K_c = \frac{0.9}{RL} \]

\[ T_i = 3L \]

\[ R = k/\tau \]

Sample values

\[ K_c = 0.04102 \]

\[ T_i = 0.825 \text{ sec} \]
Procedure

• Double click on the controller block.
• Double click on PID Controller block.
• Enter the P and I values calculated using the Ziegler-Nichols Rule.
PID Block
PID block configuration
Output

• \( K_c = 0.075 \) and \( T_i = 0.36 \) sec.
• After the speed settles at 2000 RPM, a step of 400 RPM is applied.
• It is seen that the output follows the set point and the speed settles at 2400 RPM.
• Next, a negative step of 400 RPM is applied.
• It is clearly observed that motor speed decreases and settles at 2000 RPM.
Output response
Neural Network Model And Neural Network Controller for DC Motor

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1. How to use Neural Network tools

Welcome to Neural Network Start
Learn how to solve problems with neural networks.

Getting Started Wizards More Information

Each of these wizards helps you solve a different kind of problem. The last panel of each wizard generates a MATLAB script for solving the same or similar problems. Example datasets are provided if you do not have data of your own.

Input-output and curve fitting.
Fitting app

Pattern recognition and classification.
Pattern Recognition app

Clustering.
Clustering app

Dynamic Time series.
Time Series app
2. Network Fitting GUI

Welcome to the Neural Fitting app.
Solve an input-output fitting problem with a two-layer feed-forward neural network.

Introduction

In fitting problems, you want a neural network to map between a data set of numeric inputs and a set of numeric targets.

Examples of this type of problem include estimating house prices from such input variables as tax rate, pupil/teacher ratio in local schools and crime rate. Price data (Price_dataset) estimating engine emission levels based on measurements of fuel consumption and speed (engine_dataset) or predicting a patient’s body fat level based on body measurements (bodyfat_dataset).

The Neural Fitting app will help you select data, create and train a network, and evaluate its performance using mean square error and regression analysis.

Neural Network

A two-layer feed-forward network with sigmoid hidden neurons and linear output neurons (linear), can fit multi-dimensional mapping problems arbitrarily well, given consistent data and enough neurons in its hidden layer.

The network will be trained with Levenberg-Marquardt backpropagation algorithms (trainlm), unless there is not enough memory, in which case scaled conjugate gradient backpropagation (trainscg) will be used.

To continue, click [Next].
3. Data set selection

![Neural Fitting GUI](image)

- **Select Data**
  - **Get Data from Workspace**
    - Input data to present to the network:
      - Inputs:
        - (none)
    - Target data defining desired network output:
      - Targets:
        - (none)
  - Summary:
    - No inputs selected.
    - No targets selected.

- **Want to try out this tool with an example data set?**
  - **Load Example Data Set**

- **Select Inputs and targets, then click [Next].**

- **Neural Network Start**
  - **Welcome**

- **Back**
  - **Next**
  - **Cancel**
4. Network Architecture

[Diagram showing a neural network with input, hidden, and output layers.]

- **Hidden Layer**
  - Number of neurons in the hidden layer: 10

- **Output Layer**
  - Number of neurons in the output layer: 1

Recommendation: Return to this panel and change the number of neurons if the network does not perform well after training.

Click Next to continue.
5. Train Network

The image shows a window titled "Train Network" which is used to train a network to fit the inputs and targets. The window includes options to choose a training algorithm, a description of the algorithm, and notes on training multiple times and generating different results due to different initial conditions and sampling. It also includes a button to "Train network, then click [Next]."
6. Training Results
7. Deploy Solution

- **Application Deployment**
  - Prepare neural network for deployment with MATLAB Compiler and Builder tools.
  - Generate a MATLAB function with matrix and cell array argument support.

- **Code Generation**
  - Prepare neural network for deployment with MATLAB Coder tools.
  - Generate a MATLAB function with matrix-only arguments (no cell array support).

- **Simulink Deployment**
  - Simulate neural network in Simulink or deploy with Simulink Coder tools.
  - Generate a Simulink diagram.

- **Graphics**
  - Generate a graphical diagram of the neural network.
Comparison between DC Motor Model and Neural Network Model

- Steady state output
Random Reference Signal
Neural Network Controller Replacing PID
Steady state and random reference signal tracking
Neural Network Controller with DC Motor
Contact

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