System identification of discrete model for DC motor positioning

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Abstract: - This paper presents modeling of a discrete DC motor positioning using system identification. The identification of most suitable discrete model of DC motor was done by using MATLAB/Simulink. The best discrete model was determined by testing with four different sampling times. Result presented shows that the best model achieved performance of 87.79% at 55ms sampling time.

Key-Words: - System identification, DC Motor, discrete model, MATLAB/Simulink

1 Introduction

Mathematical models are required in control system design in order to describe the system dynamics, and identification processes [1]. Continuous time models tend to be preferred as compared to discrete-time models in control system design, because the relation between pole zeros and time responses of the models is understood easily [2]. However, as computers advances, a lot of system identification (SI) methods benefiting from the digital processing have been developed, and identification for discrete-time systems has been studied to facilitate the analysis and data processing.

The two control aspects taken into account in DC motor are the position and velocity control. From these control aspects, two plant models can be identified, one for which the rotor velocity will be the output and another for which the rotor position is the output. Position control systems are an important component of many industrial products. Examples are found in disc drive, automotive products, robotics, process control and many others. Servo systems are generally controlled by conventional Proportional – Integral – Derivative (PID) controllers, since they can be designed easily, offer low cost, inexpensive maintenance and effectiveness [3].

Up to now, works and papers on the optimal control and suboptimal control problems of discrete large-scale time-delay systems are seldom seen. But as the wide spreading of computer-based control systems and the fact that time-delay widely exists, the study of these problems is of increasing importance [4].

Most of the PID controller was designed using continuous-time system and have been applied widely especially in industrial application. If the system needs to be analyzed in terms of discrete-time, the users will encounter the difficulties in solving the system approach. In relation to the problems above, the objective of this paper is to illustrate modeling of a discrete DC motor positioning control.

2 DC Motor

Dc-motor controlled through a servo amplifier. The Servo Amplifier (SA150D) is connected to the DCM150F through a special connector inserted in front socket of SA150D. On the Dc-motor shaft a disc is attached. The disc is used together with the LU150L magnetic brake to simulate a load using the eddy current effect. This magnet can be raised or lowered to simulate smaller or greater motor load. According to its position, the Dc-motor and load system dynamics will change. As shown in figure 1, the PMS mechanical unit consists of a Dc-motor, Tachometer/Gearbox, Digital Encoder, Input and Output potentiometers and magnetic brake.

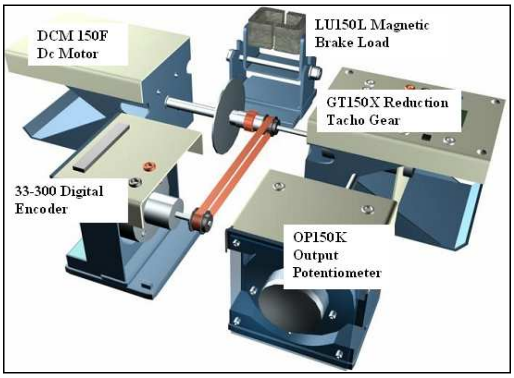

Fig. 1 Modular Servo mechanical Unit

3 Model Definition

Before system identification can be applied, the plant model is first derived from the measured input and output signals of a real DC-motor. The PC with the Advantech I/O PCI card 1711 and the Matlab and Simulink environment serves as the main control unit.

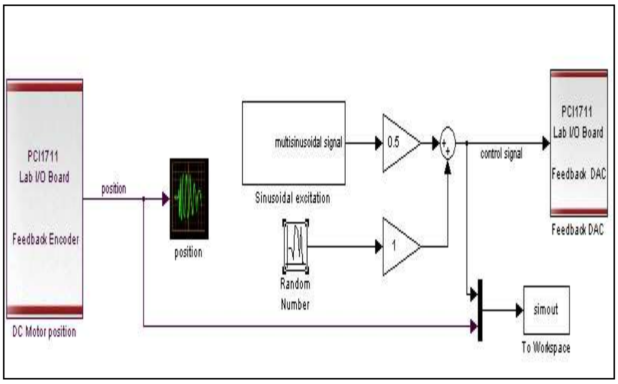

Fig. 2 Position Model Identification interface with Real time

Fig.2 show the position model identification interfacing with the Modular Servo mechanical unit used to collect input-output data. The good parameters identification requires the usage of input signal that are rich in frequencies. This plant model use excitation signal because of the fact that it holds very broad frequency content thus the whole dynamics of the plant can be identified. Due to the dynamics of this plant is not too complex, four different frequencies are summed to produce a satisfactory excitation signals.

To obtain the best fit model for this plant, four different sample times were chosen during experiment that are 1ms, 45ms, 50ms, and 55ms. As far as the discrete models are concerned, the most suitable structure choice for DC motor is ARX model. The ARX block uses least-squares analysis to estimate the parameters of an ARX model and returns the estimated model as an idpoly object.

3.1 ARX Model Definition

The ARX model is defined, as follows:

$$y(t) + a_1 y(t-1) + ... + an_a y(t-n_a) = b_1 u(t-1) + ... + bn_b u(t-n_k-n_b+1) + e(t) \quad (1)$$

Where

- *y(t)* is the output at time t.
- $a_1 \cdots a_n$ and $b_1 \cdots b_n$ are the parameters to be estimated.
- n_a is the number of poles of the system.
- $n_b - 1$ is the number of zeros of the system.
- n_k is the number of input samples that occur before the inputs that affect the current output.
- $y(t-1) \ldots y(t-n_a)$ are the previous outputs on which the current output depends.
- $u(t-n_k) \ldots u(t-n_k-n_b+1)$ are the previous inputs on which the current output depends.
- *e(t)* is a white-noise disturbance value.

The ARX model can also be written in a compact way using the following notation:

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

where

$$A(q) = 1 + a_1 q^{-1} + \cdots + a_{n_a} q^{-n_a}$$
$$B(q) = b_1 + b_2 q^{-1} + \cdots + b_{n_b} q^{-n_b+1}$$

and q^{-1} is the backward shift operator, defined by

$$q^{-1}u(t) = u(t-1) \quad (3)$$

Fig. 3 shows the ARX model structure. The block accepts two inputs, corresponding to the measured input-output data for estimating the model. The first input is Input signal and second input is output signal. The ARX Estimator block outputs a sequence of multiple models (`idpoly` objects), estimated at regular intervals during the simulation.

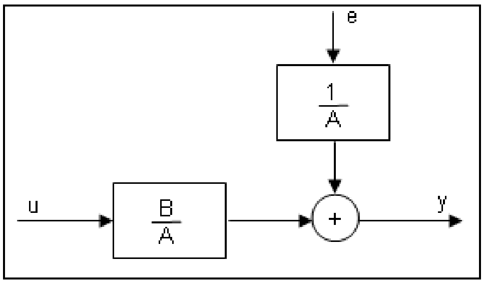

Fig. 3 ARX model structure

3.1 Model Evaluation

The performance of the models under investigation is evaluated based on two criteria, Akaike's Final Prediction Error, FPE and Akaike's Information Criteria, AIC.

$$PFE = V\frac{(1+d/N)}{(1-d/N)} \quad (4)$$

where

V is loss function

$$V = \frac{e^2(k)}{N} = \frac{e^{\mathrm{T}}(k)e(k)}{N} \quad (5)$$

And e(k) is error vector.
d is number of approximated parameters
N is number of samples.

$$AIC = \log(V.(1+2d/N)) \quad (6)$$

AIC provides a measure of model quality by simulating the situation where the model is tested on a different data set. After computing several different models,the models can be compared using this criterion. Akaike's theory stated that, the most accurate model gives the smallest AIC[5].

4 System Identification

System identification (SI) is the art and science of building mathematical models from measured input-output data[6]. In order to obtain ARX model from input-output data, the Matlab System Identification Toolbox is used.

4.1 SI Procedure

The process of SI with ident involves the following four steps:

1. Importing data into ident as shown in Fig. 4 from the workspace and substitute the input-output into it.

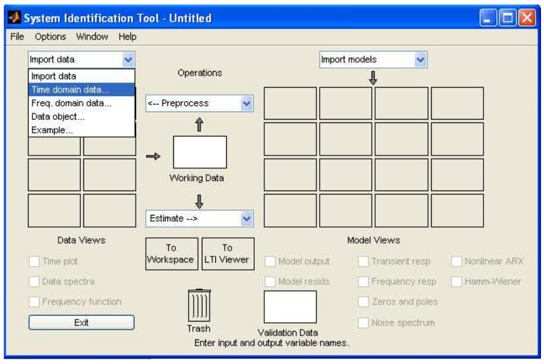

Fig. 4 selecting time domain data in import data window

2. Preprocessing data (or preparing the data for estimation) as shown in Fig. 5 where data have been divided into working and validation data using select range.

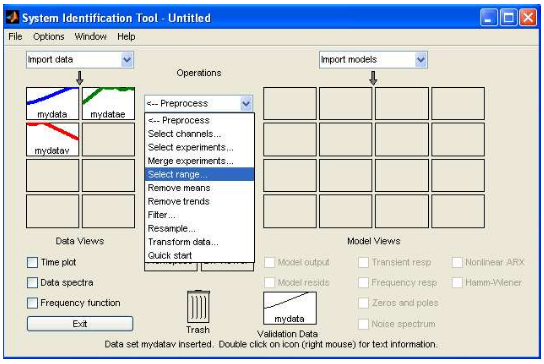

Fig. 5 Preprocess data

3. Estimating models based on the working data set as shown in Fig. 6. This is use to generate dynamic linear models with different structures, orders, and delays. A model structure characterizes the relationship between the input and output data, and between unknown noise sources and the output data.

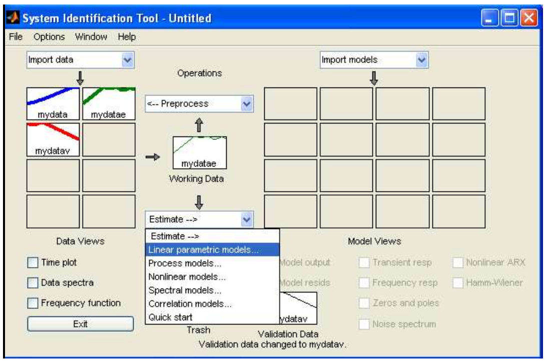

Fig. 6 Estimating data

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4. Analyzing the model as shown in Fig. 7 where there are six views for examining models that are model output, model residual, transient response, frequency response zeros and poles as well as noise spectrum.

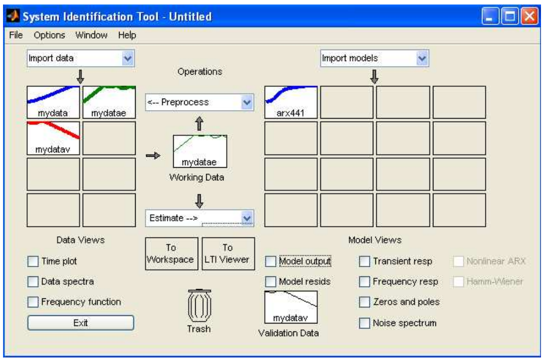

Fig. 7 Suitable structure is added to the model views.

5 Results

Four different sampling times were chosen to be tested in order to obtain the best fit discrete model for DC motor. Fig. 8 shows the model using 1ms sampling time by producing 20001 samples. This model could give the best fit of 17.52%. Based on Akaike's Final Prediction Error, FPE and Akaike's Information Criteria, AIC values that are too large, thus this model cannot be accepted.

Then Fig. 9 and Fig.10 shows model outputs for 45ms and 50ms sampling time. These models give 79.9% and 85.96% with 445 and 400 samples respectively. Fig. 11 show the model of 87.79% by using 364 samples of data for sampling time of 55ms.

Table 1 illustrates the tabulated results of the four sampling time tested. From the table, sampling time of 55ms give the smallest values of FPE and AIC. Therefore, this model can be accepted as the best model for DC motor.

Fig. 12 show the step response of the identified model from the best fit model of Fig. 11. Note that the models was obtained strongly depend on the magnetic brake position which simulates different load. Every time the magnet position is changed, the model should be updated.

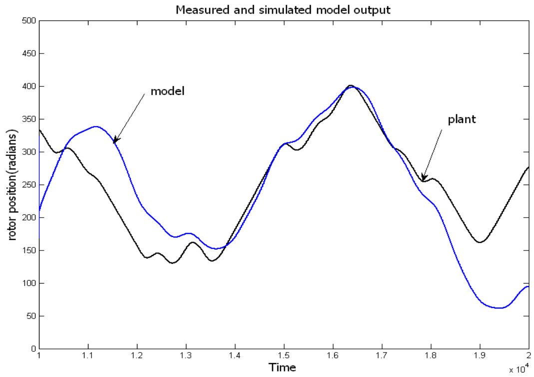

Fig. 8 The model and plant output signal using 1ms sampling time

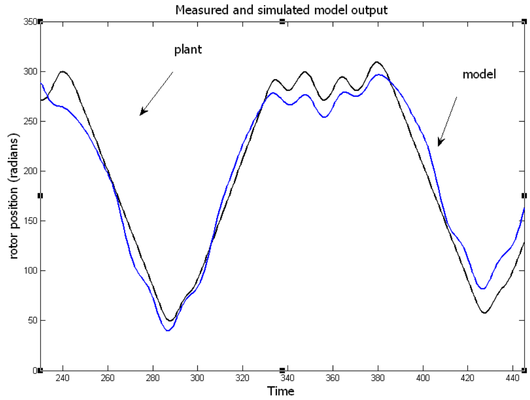

Fig. 9 The model and plant output signal using 45ms sampling time.

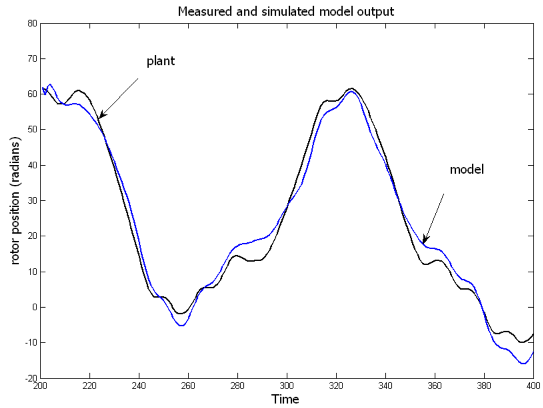

Fig. 10 The model and plant output signal using 50 ms sampling time.

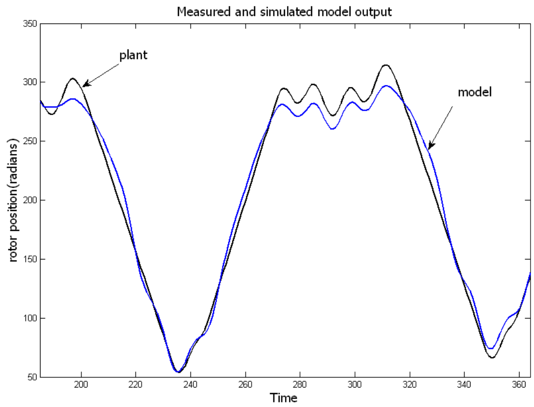

Fig. 11 The model and plant output signal using 55 ms sampling time.

Sampling time(ms)	Loss function	FPE	AIC	Best fit (%)
1	3.6566e-006	3.6644e-006	4.6608e-009	17.52
45	0.0445304	0.0482607	8.8256e-005	79.90
50	0.0108665	0.01190	0.0014181	85.96
55	0.09253	0.102339	0.00021516	87.79

Table 1: Comparison of the best fit model

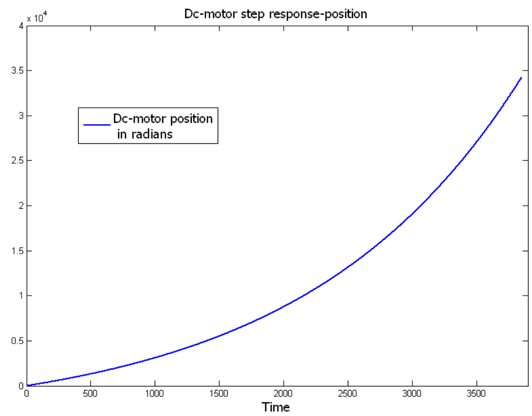

Fig. 12 Identified model response

6 Conclusion

The chosen sampling time tested produced comparative value of FPE and AIC that verified the best discrete model of DC-motor using SI gives the best fit of 87.79% at a sampling time of 55ms.

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