

Fig. 2. Experimental setup.

### 3. Experimental results

#### 3.1. Experimental setup

The laboratory prototype consist of a servomotor from Moog, model C34-L80-W40 (Fig. 2) driven by a Copley Controls power servoamplifier, model 423, configured in current mode. A BEI optical encoder, model L15 with 2500 pulses per revolution, allows measuring the servomotor position. The algorithms are coded using the MacLab/Simulink software platform under the program Wincon from Quanser Consulting, and a Quanser Consulting Q8 board performs data acquisition. The data card electronics increases four times the optical encoder resolution up to  $2500 \times 4 = 10\,000$  pulses per revolution. The control signal produced by the Q8 board passes through a galvanic isolation box. The software runs on a personal computer using an Intel Core 2 quad processor, and the Q8 board is allocated in a PCI slot inside this computer. The following transfer function, which is composed of a high-pass filter in cascade with a low-pass filter, allows obtaining velocity estimates from position measurements.

$$G(s) = \frac{400s}{s + 400} \frac{500}{s + 500}$$

The low pass filter attenuates the high frequency components of the position signal. The Simulink diagrams use a sampling period of 0.1 ms and the ODE5 solver. Fig. 2 depicts the experimental setup.

#### 3.2. Experiments

##### 3.2.1. Parameter identification

Two Duffing systems generate the signal used for exciting the servomechanism

$$\dot{x}_{11} = x_{21} \omega_1 \pi \quad (31)$$

$$\dot{x}_{21} = [-0.25 + x_{21} + x_{11} - 1.05x_{11}^2 + 0.3 \sin(\omega_1 \pi t)] \omega_1 \pi; \quad i = 1, 2$$

$$x_{1i} = 7x_{11} - 5x_{22}; \quad x_{21}(0) = 0; \quad x_{22}(0) = 0;$$

$$\omega_1 = 1 \text{ rad/s}; \omega_2 = 2 \text{ rad/s}.$$

This type of chaotic excitation was proposed in [24] for parameter identification of a speed controlled servomotor. Fig. 3 shows the time evolution of  $x_{11}$ . The gains for the PD controller are  $k_p = 10$  and  $k_d = 0.28$ , and the update law gains are  $\Gamma = \text{diag}\{12 \ 3000 \ 180 \ 90\}$ .

Fig. 4 shows the time evolution of the parameter estimates obtained using the proposed approach. Fig. 5 depicts the input error  $e_u$  and the evaluation of the PE condition (30) with  $v = \frac{1}{2} [1 \ 1 \ 1 \ 1]^T$ ; the values for the PE condition in Fig. 5(b) are

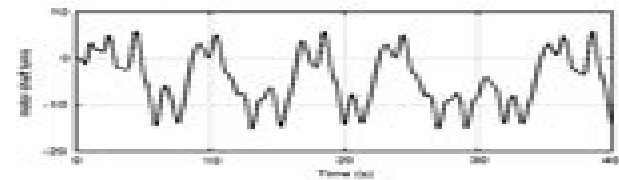
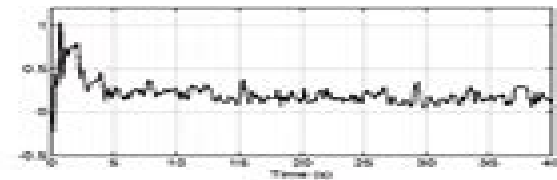
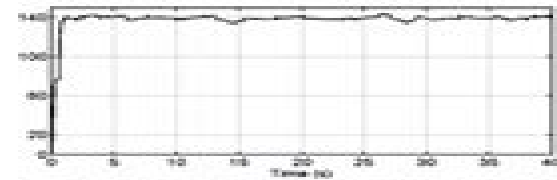
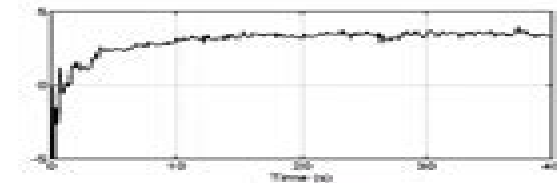
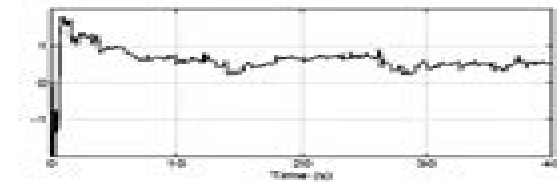


Fig. 3. Chaotic excitation signal.

Parameter estimate  $\hat{a}$ Parameter estimate  $\hat{b}$ Parameter estimate  $\hat{c}$ Parameter estimate  $\hat{d}$ Fig. 4. Parameter estimates obtained using the CLIE method:  $\hat{a}$ ,  $\hat{b}$ ,  $\hat{c}$ , and  $\hat{d}$ .

shown every five seconds, i.e.  $\delta = 5$  s. Hence, the regressor vector fulfills the PE condition during the experiment. Table 1 shows the parameter estimates obtained from the experiment. They were

# Servomechanism Analysis

**Arthur L. Jones, Benjamin R. Briggs**



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