DC Motors Modeling Resorting to a Simple Setup and Estimation Procedure

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Abstract. This paper describes a procedure applied to model DC motors. An example of the procedure apply is shown for a 12V brushed DC motor, equipped with a 29:1 metal gearbox and an integrated quadrature encoder. It is described the developed setup applied to obtain the experimental data and the developed algorithm applied to estimate the actuator parameters. It was obtained an electro-mechanical dynamical model that describes the motor, its gear box and the encoder. The motivation to develop a simple and easy to assemble procedure that allows to model DC motors is due to the fact that these actuators are intensively used in mobile robotics, being realistic simulation, based in accurate sensor and actuator models, the key to speed up Robot Software developing time.

Keywords: Actuators, Sensors, Modeling, Simulation.

1 Introduction

This paper describes a procedure applied to model DC motors. An example of the procedure apply is shown for a 12V brushed DC motor, equipped with a 29:1 metal gearbox and with an integrated quadrature encoder. A detailed description of the referred DC Motor can be found in [1].

It is described the developed setup applied to obtain the experimental data and the developed algorithm applied to estimate the actuator parameters. It was obtained an electro-mechanical dynamical model that describes the motor, its gear box and the encoder. The goal of the actuator model parameters estimation is to provide more models that can be used in SimTwo, which is illustrated in Figure 1, being a realistic simulation software that can support several types of robots. Its main purpose is the simulation of mobile robots that can have wheels or legs, although industrial robots, conveyor belts and lighter-than-air vehicles can also be defined. Basically any type of terrestrial robot definable with rotative joints and/or wheels can be simulated in this software [2] [7] [8].

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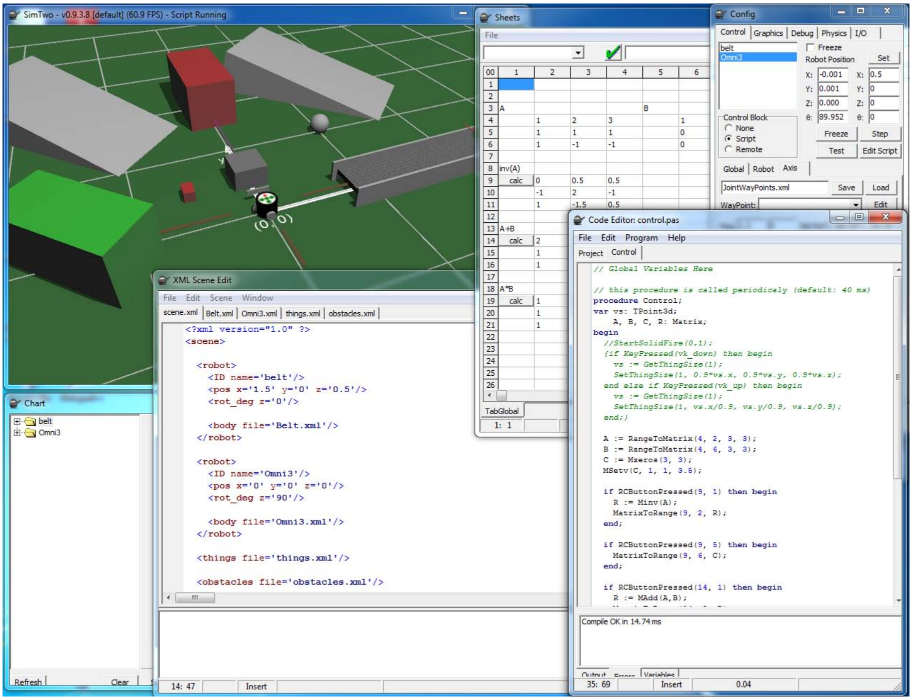

Fig. 1. SimTwo 3d View

The motivation to develop a simple and easy to assemble procedure that allows to model and simulate DC Motors is due to the fact that these actuators are are intensively used in mobile robotics and because realistic simulation, based on accurate sensor and actuator models is the key to speed up Robot Software developing time [6].

The paper is organized as follows: After a brief introduction it is described the developed setup applied to obtain the experimental data and the actuator parameters estimation. Finally some conclusions and future work are presented.

2 DC Motor Experimental Setup

DC motors are actuators worldwide popular in the mobile robotics domain [5]. The fact that a DC motor is equipped with encoders is an important feature because it provides important data to obtain the closed loop velocity control and to obtain relative measurements based on the odometry calculation [3]. The chosen DC Motor is a 12V brushed DC motor, equipped with a 29:1 metal gearbox and an integrated quadrature encoder, being shown in Figure 2.

In order to obtain experimental data the setup, shown in Figures 3 and 4, was implemented. The experimental setup is based on an Arduino Uno programmed in C, a PC software application developed in Free Pascal (Remote),

Fig. 2. 12 V DC Geared Motor [1]

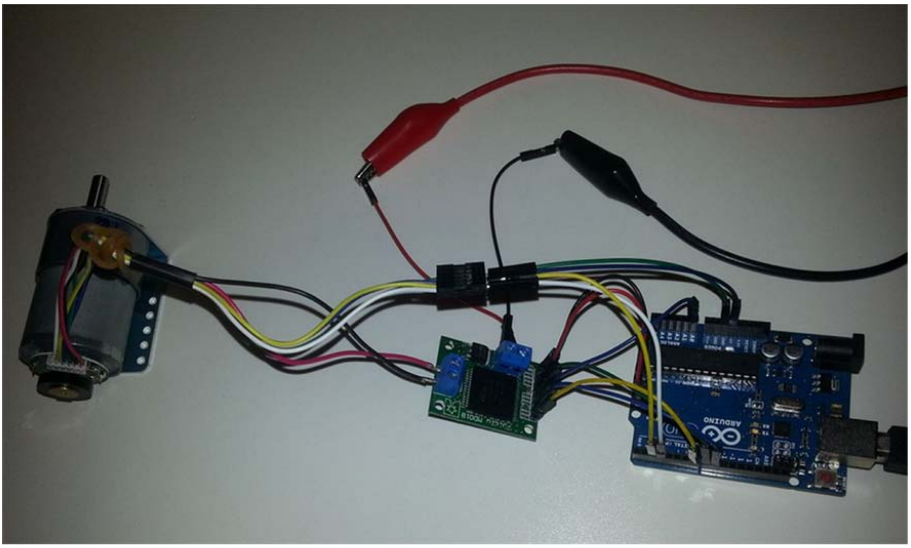

Fig. 3. Experimental setup

the VNH3SP30 Drive, a DC Power source and a DC motor without Load. The registered data is the load angular velocity and the input voltage. Two tests were performed, the first was to obtain the step response for a 12 Volt input (transitory response data) and the second test was the steady state response for several input voltages (steady state data).

3 DC Motor Parameters Estimation

The DC Motor model can be defined by the following equations, where U_a is the converter output, R_a is the equivalent resistor, L_a is the equivalent inductance and e is the back emf (electromotive force) voltage as expressed by equation (1).

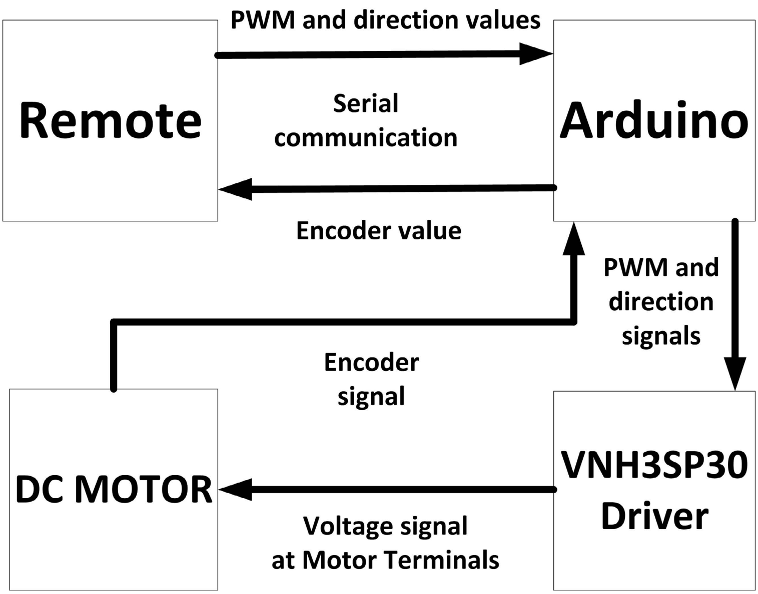

Fig. 4. Experimental setup block diagram

$$U_a = e + R_a i_a + L_a \frac{\partial i_a}{\partial t} \tag{1}$$

The motor can provide a torque T_L that will be applied to the load, being the developed torque (T_d) subtracted by the friction torque, wich is the sum of the static friction (T_c) and viscous friction ($B\omega$), as shown in equation 2.

$$T_L = T_d - T_c - B\omega \tag{2}$$

Current i_a can be correlated with the developed torque T_d through equation (3), the back emf voltage can be correlated with angular velocity through equation (4) and the load torque T_L can be correlated with the moment of inertia and the angular acceleration through equation 5 [4].

$$T_d = K_s i_a \tag{3}$$

$$e = K_s \omega \tag{4}$$

$$T_L = J\dot{\omega} \tag{5}$$

Resorting to equation 2, equation 3 and equation 5, equation 6 was obtained.

$$\dot{\omega} = \frac{K_s i_a - T_c - B\omega}{J} \tag{6}$$

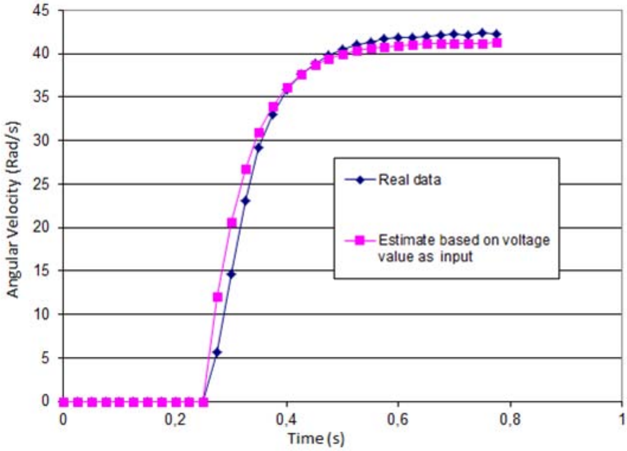

Fig. 5. Motor transitory response data

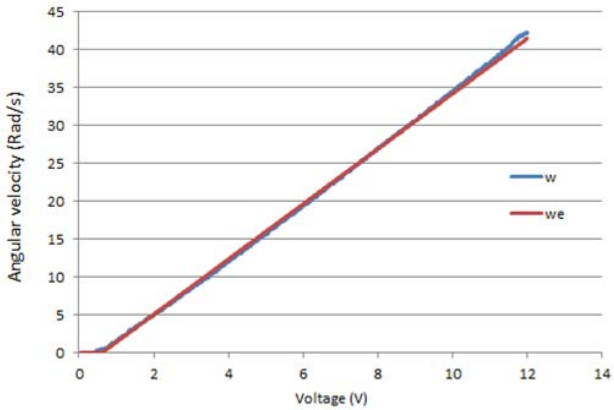

Fig. 6. Motor steady state response data

Table 1. DC Motor estimated parameters

Parameters	Value
K_s	2.64E-1
L_a	3.4E-3
R_a	3.5486
B	7.06E-4
T_c	4.6604E-2
J	1.47E-3

After discretizing equation 6, applying the Euler method, equation 7 is obtained, where ΔT is the sampling time (25 ms).

$$\omega[k] = \omega[k-1] + \Delta T \frac{K_s i_a[k-1] - T_c - B\omega[k-1]}{J} \tag{7}$$

By minimizing the sum of the absolute error between the estimated (equation 7) and the real transitory response data (assuming initial know values for T_c and K_s), parameters B and J were estimated. Then using equations 1, 2, 3, 4 and 5 and assuming that voltage drop due to L_i is negligible, equation 8 is obtained.

$$J\dot{\omega} = \frac{K_s}{R_a}(U_a - K_s\omega) - B\omega - T_c \tag{8}$$

Solving the first order differential equation, equation 9 is obtained:

$$\omega(t) = \frac{a}{b}(1 - e^{-bt}) \tag{9}$$

where:

$$a = \frac{K_s U_a - R_a T_c}{R_a J} \tag{10}$$

$$b = \frac{K_s^2 + R_a B}{R_a J} \tag{11}$$

In steady state $\omega = \frac{a}{b}$, resulting in equation 12.

$$\omega = \frac{K_s}{K_s^2 + R_a B} U_a - \frac{R_a T_c}{K_s^2 + R_a B} \tag{12}$$

By minimizing the absolute error between estimated and the steady state data, assuming an initial value for R_a, parameters K_s and T_c are estimated. Finally resorting to equation 9, by minimizing the absolute error between the estimated data and the transitory response data, R_a is estimated. The described optimization process must be repeated until the estimated parameters converge to their true values. Parameters such as T_c, R_a and K_s that are initially assumed as known are replaced by the estimated ones, every time the estimate process is repeated. The estimated and the real transitory and steady state responses are shown in Figures 5 and 6 respectively.

The estimated parameters, in SI Units, are shown in Table 1, where the equivalent inductance values is measured.

4 Conclusions and Future Work

This paper describes a simple procedure applied to model DC Motors. As an example of the procedure apply it is shown the modeling of a 12V brushed DC motor, equipped with a 29:1 metal gearbox and with an integrated quadrature encoder. It was described the developed setup applied to obtain the experimental data and the algorithm applied to estimate the actuator parameters. It is obtained an electro-mechanical dynamical model that describes the motor, its gear box and the encoder. The motivation to develop a simple and easy to assemble procedure that allows to model DC motors is due to the fact that these actuators are intensively used in mobile robotics, being realistic simulation, based in accurate sensor and actuator models the key to speed up Robot Software developing time.

As future work the authors intend to test the presented procedure in the modeling of different DC motors, whenever a new robot prototype is assembled.

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