Modeling and simulation of the EMG30 Geared motor with encoder resorting to SimTwo: The official Robot@Factory Simulator

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ABSTRACT

This paper describes the EMG30 mechanical and electrical modeling and its simulation resorting to SimTwo (Robot@Factory mobile robot competition official simulator). It is described the developed setup applied to obtain the experimental data that was used 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 model and simulate the EMG30 is the fact that it is an actuator worldwide popular in the mobile robotics domain, being a low cost 12v motor equipped with encoders and a 30:1 reduction gearbox. The Goal of this work is to provide more realism and new features to the Robot@Factory official simulator, allowing participating teams to produce and validate different robot prototypes and its software, reducing considerably the development time.

1. INTRODUCTION

Robotic competitions are an excellent way to foster research and to attract students to technological areas [1]. The robotic competitions present standard problems that can be used as a benchmark, in order to evaluate and to compare the performances of different approaches. Although there are many robotic competitions [2-5], there is the need to create new ones, in order to solve new challenges. The factory environment is a prime candidate to use robots in a variety of tasks. A competition where mobile robots are tackling transportation problems in the shop floor is a challenge that can foster new advances in service robots and manufacturing [6-7]. The Robot@Factory competition presents problems that occur when using mobile robots to perform transportation tasks. The robots must be able to navigate, cooperate and to self-localize in an emulated factory plant, to transport and handle materials in an efficient way [8].

This paper describes the EMG30 mechanical and electrical modeling and its simulation resorting to SimTwo. SimTwo is 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 [9].

The motivation to model and simulate the EMG30 is the fact that it is an actuator worldwide popular in the mobile robotics domain, being a low cost 12v motor equipped with encoders and a 30:1 reduction gearbox, and also to provide more realism and new features to SimTwo (the Robot@Factory official simulator), allowing participating teams to produce and validate different robot prototypes and its software, reducing considerably the development time. 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. Then its simulation resorting to SimTwo is presented. Finally some conclusions and future work are presented.

2. MODELING OF THE EMG30 ACTUATOR

The EMG30 is an actuator worldwide popular in the mobile robotics domain, being a low cost 12v motor equipped with encoders and a 30:1 reduction gearbox. The fact that it 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 [10]. An EMG30 is shown in Figure 1.

Figure 1. EMG30 Geared motor

The EMG30 model can be defined by the following equation, where U_a is the converter output, R_a is the equivalent resistor, L_a is the equivalent inductance, e is the back emf (electromotive force) voltage, I_a is the motor current as expressed by equation (1).

$$U_a = e + R_a i_a + L_a \frac{di_a}{dt} \tag{1}$$

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, which is the sum of the static friction T_c and viscous friction, 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) [11].

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

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

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

In order to obtain experimental data, a setup, shown in Figure 2, was implemented. The experimental setup is based on the Arduino micro-controller, the L6207 Drive, a DC Power source, an EMG30 actuator and the motor Load. The obtained data is the load angular velocity, the input voltage and the motor current. 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). Resorting to equation (2), equation (3) and equation (5), equation (6) was obtained.

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

After discretizing equation (6), equation (7) was obtained, where ΔT is the sampling time (50 ms).

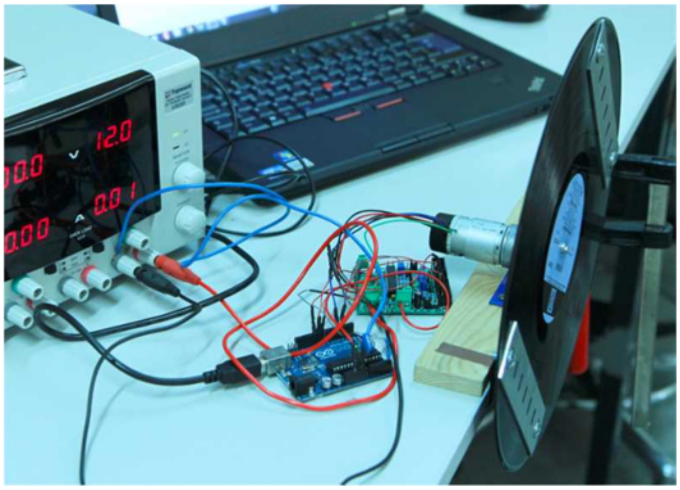

Figure 4.Experimental setup.

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

By minimizing the sum of the absolute error between the estimated (7) and the real transitory response data (assuming initial know values for R_a 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_a 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:

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

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

In steady state $\omega = a/b$, resulting in equation (12).

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

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 Figure 3.

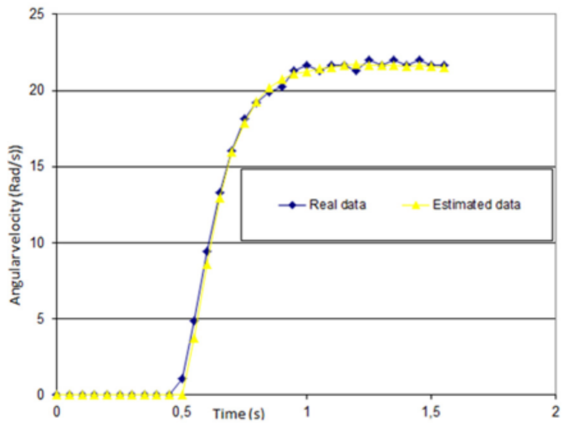

Figure 3a.Motor transitory response.

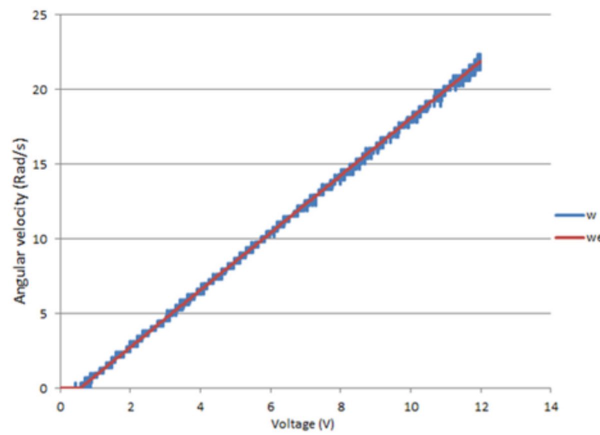

Figure3b. Motor steady state response data

The load has a known moment of inertia, given by the sum of three moments of inertia. A moment of inertia of a vinyl record $J_d = 0.5\, m_d r_d^2$ (where m_d is the record mass and r_d is its radius) summed with the moments of inertia of two planar rectangles, each one given by the equation Jr=m $(a^2+b^2)/12$ (where a and b are the planar rectangles sides dimensions and m is the planar rectangles mass). Having in mind that the **Parallel axis theorem** has to be used in order to calculate the moment of inertia of the planar rectangles, $m\, r_p^2$ has to be summed to the previous calculated moment of inertia (where m is the rectangular plane mass and r_p is the perpendicular distance between the axis of rotation and the axis that would pass through the Centre of mass of each rectangular plane) [12]. In order to estimate the motor moment of inertia it is subtracted to the estimated value J the calculated moment of inertia, being J_L the load moment of inertia and J_M the moment of inertia. The estimated parameters are shown in Table 1, where the presented equivalent inductance was directly measured.

Table 1: EMG30 estimated parameters

Parameters	Value
k_s	0.509
L_a	3.4E-3
R_a	7.101
B	0.000931
T_c	0.0400
J	0.00567
J_M	0.00377
J_L	0.0019

3. SIMULATION OF THE EMG30 RESORTING TO SIMTWO

SimTwo is the official simulator of the Robot@Factory competition. The competition arena, shown in Figure 4, emulates a factory shop floor where there are warehouses and machinery. A real robot prototyped with the EMG30 actuator moving in the competition arena is shown in Figure 5.

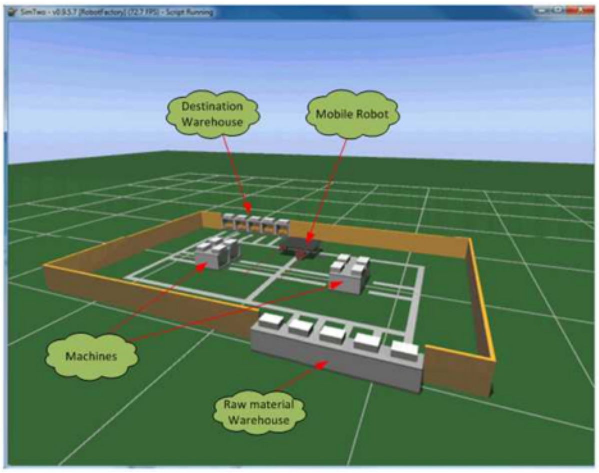

Figure 4.Competition arena modeled in the SimTwo.

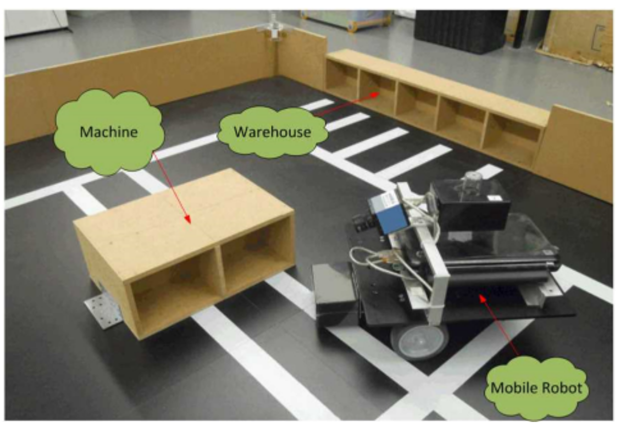

Figure 5. Robot in the competition arena.

In this section it is presented an example of a simulation of the EMG30 motor, being a very popular actuator among teams participating in the Robot@Factory competition. The experimental setup presented in section 2 was simulated resorting to SimTwo, a snapshot of its simulation is shown in Figure 6. The presented previously experiments were simulated, the real results and the simulated are shown in Figure 7.

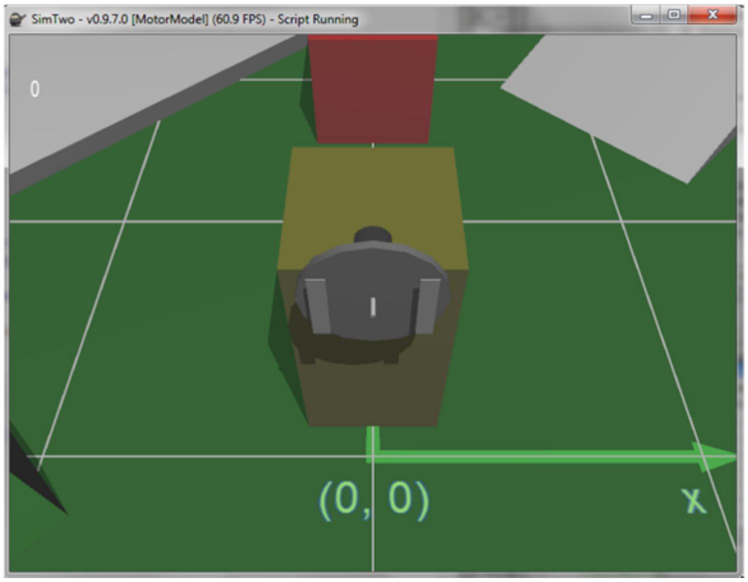

Figure 6. EMG30 simulated in SimTwo

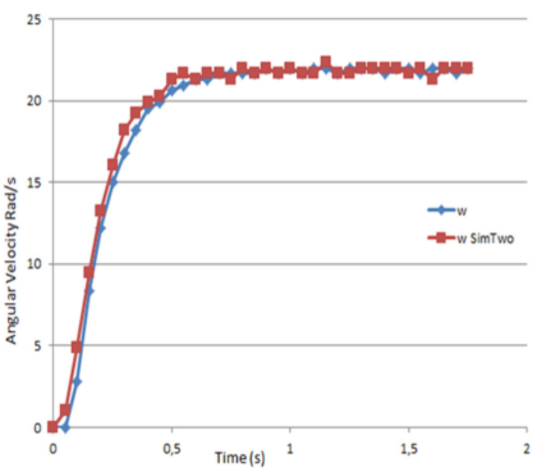

Figure 7 a). Actuator transitory response

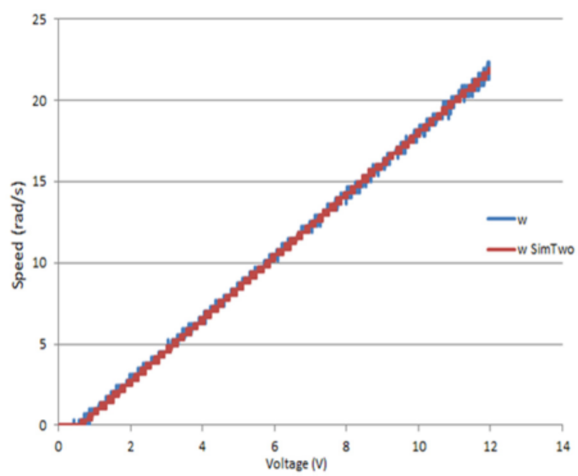

Figure 7 b). Actuator steady state response

5. Conclusions

In this paper it is presented the EMG30 mechanical and electrical modeling and its simulation resorting to SimTwo (Robot@Factory mobile robot competition official simulator). It is described the developed setup applied to obtain the experimental data, that was used 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 model and simulate the EMG30 was the fact that it is an actuator worldwide popular in the mobile robotics domain, and in particular in the Robot@Factory participating teams, being a low cost 12v motor equipped with encoders and a 30:1 reduction gearbox. The referred robot competition can play an important role in education due to the inherent multi-disciplinary concepts that are involved, motivating students to technological areas. It also plays an important role in research and development, because it is expected that the outcomes that will emerge here, will later be transferred to other application areas, such as service robots and manufacturing. As future work the authors intend to produce robot code resorting to SimTwo with a robot prototyped with EMG30 actuators and apply it to the real robot.

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REFERENCES

[1] Almeida, L., Azevedo, J., Cardeira, C., Costa, P., Fonseca,P., Lima, P., Ribeiro, F., and Santos, V.: "Fostering advances in research, development and education in robotics", Proceedings of the 4th Portuguese conference in Automatic Control, 2000.

[2] Browning, B., Bruce, J., Bowling, M., and Veloso, M.: "Ustp: Skills, tactics and plays for multi-robot control in adversarial environments", IEEE Journal of Control and Systems Engineering., 2005.

[3] Lund, H. and Pagliarinis, L.: " Robocup jr. with lego mindstorms ", International Conference on Robotics and Automation, San Francisco, CA, IEEE, 2000.

[4] Nakanishi, R., Bruce, J., Murakami, K., Naruse, T., and Veloso, M.: " Cooperative 3-robot passing and shooting in the robocup small size league. ", In Proceedings of the RoboCup Symposium, Bremen, Germany, 2006.

[5] Ribeiro, F., Moutinho, I., Silva, P., Fraga, C., and Pereira, N.: " Controlling omni-directional wheels of a robocup msl autonomous mobile robot ", In Scientific Meeting of the Portuguese Robotics Open, 2004.

[6] Yuta, S., Asama, H., Thrun, S., Prassler, E., and Tsubouchi, T.: " Field and Service Robotics, Recent Advances in research and Applications. ", volume 24 of Springer Tracts in Advanced Robotics, Lake Yamanaka, Japan, 14-16 July 2003.

[7] Arun N. Nambiar: " Challenges in Sustainable Manufacturing. ", Proceedings of the 2010 International Conference on Industrial Engineering and Operations Management, Dhaka, Bangladesh, January 9-10, 2010.

[8] Gonçalves, J., Costa, P., Lima, J., and Moreira, A.: "Manufacturing Education and Training resorting to a new mobile robot competition ", Flexible Automation Intelligent Manufacturing (FAIM), Ferry Cruise Conference Helsinki-Stockholm-Helsinki, 10-13 June 2012.

[9] Costa, P., Gonçalves, J., Lima, J., and Malheiros, P.: " Simtwo realistic simulator: A tool for the development and validation of robot software ", International Journal of Theory and Applications of Mathematics Computer Science, 2011.

[10] Borenstein, J., Everett, H., Feng, J.: " 'Where am I?' Sensors and Methods for Mobile Robot Positioning ", Technical Report, The University of Michigan, 1996.

[11] Bishop, R.: " The Mechatronics Handbook ", CRC Press, New York, 2002.

[12] Ramsey, A.: " Dynamics ", Cambridge Library Collection - Mathematics, 2009.