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Proposal of a Low cost Mobile Robot Prototype with On-Board Laser Scanner: Robot@Factory Competition Case Study

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Abstract: This paper presents the proposal of a Low cost Mobile Robot prototype with On-Board Laser Scanner, prototyped to compete at the Robot@Factory Mobile Robot competition. The robot is equipped with a hacked Neato XV-11 Laser Scanner, being a very low cost alternative, when compared with the current available laser scanners. It is presented the description of its sensors and actuators, providing valuable information that can be used to develop better designs of controllers and localization systems. The robot is equipped with the 37Dx52L, which is a low cost 12v motor equipped with encoders and a 29:1 reduction gearbox, being a very popular actuator in the mobile robotics domain. The robot is also equipped with an USB camera applied to acquire image, that will be processed, in order to provide information concerning the part material status.

Keywords: Mobile Robots, Prototyping, Sensors, Actuators

1. INTRODUCTION

Nowadays the industry faces the need to have plants more and more flexible. For some tasks, like raw material transportation from one place of work to another, AGVs can be used in order to allow flexible layouts. Theses transporters perform their tasks in a dynamic work environment where unexpected obstacles may appear: the workers can cross the robot path, material left behind can block the intended route and even other robots can be an obstacle (1)(2)(3)(4)(5). Currently, the search for increased efficiency in a plant is a common activity and so AGVs and their deployment becomes a reason of an intense scientific research and pedagogical attention. This topic include fields like: control, localization and navigation. Observing that paradigms, the Robot@Factory competition was designed as a test platform that can be used to solve problems similar to those present in future real plants. The Robot@factory competition attempts to recreate a problem similar to the one that an autonomous robot will face during its use in a plant. This scaled plant has a supply warehouse, a final product warehouse and eight processing machines (6).

The prototyped robot, was projected and prototyped so that it could be low cost and enter the Robot@Factory in a competitive way. The rules limit its size to a 45*x*40 cm and 35 cm high box. The locomotion system can be built according to different topologies, for example differential, omnidirectional or *Ackerman*. It was adopted an omnidirectional topology with three wheels where there are 120° between each wheel axis. This choice allows independent translation and rotation movements. The four wheel configuration, while having some advantages, requires a mechanical suspension system.

Fig. 1. Robot Prototype

The robot, shown in Figures 1 and 2, is equipped with the 37Dx52L, which is a low cost 12v motor equipped with encoders and a 29:1 reduction gearbox, being a very popular actuator in the mobile robotics domain. The robot is also equipped with a hacked Neato XV-11 Laser Scanner, being a very low cost alternative, when compared with the current available laser scanners. Neato XV-11 is a robot that includes a low cost 360° laser scanner, this sensor can be extracted from the robot, allowing robotics practitioners to use it in their projects.

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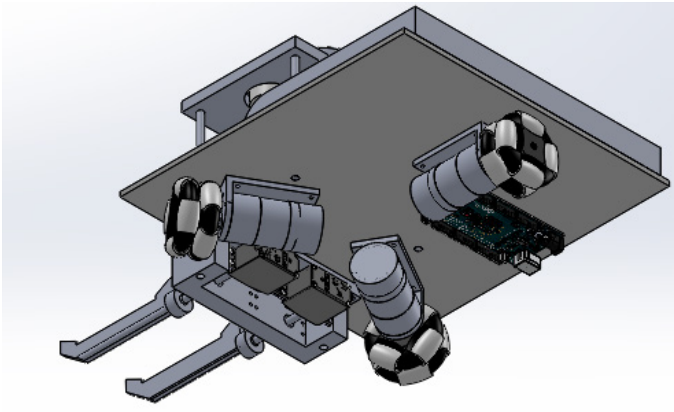

Fig. 2. Robot Prototype CAD

The prototyped robot sensors and actuators are described in the next bsections, finally some conclusions and future work are presented.

2. 37DX52L GEARED MOTOR

The 37Dx52L is an actuator worldwide popular in the mobile robotics domain, being a low cost 12v motor equipped with encoders and a 29:1 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 (16). A 37Dx52L is shown in Figure 3.

Fig. 3. 37Dx52L Geared Motor.

The 37Dx52L 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).

$$U_a = e + R_a I_a + L_a \dot{I}_a \quad (1)$$

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 ($B\omega$), as shown in equation 2.

$$T_L = T_d - T_c - B\omega \quad (2)$$

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 (17).

$$T_d = K_s I_a \quad (3)$$

$$e = K_s \omega \quad (4)$$

$$T_L = J\dot{\omega} \quad (5)$$

In order to obtain experimental data, a setup was implemented. The experimental setup is based on the Arduino micro-controller, the L6207 Drive, a DC Power source and a 37Dx52L actuator. The obtained data is the motor angular velocity and the input voltage. Two tests were performed, the first was to obtain a step response (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.

$$\dot{\omega} = \frac{K_s I_a - T_c - B\omega}{J} \quad (6)$$

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

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

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.

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

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

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

where:

$$a = \frac{K_s U_a - R_a T_c}{R_a J} \quad (10)$$

$$b = \frac{K_s^2 + R_a B}{R_a J} \quad (11)$$

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

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