TraxBot
Assembling and Programming of a Mobile Robotic Platform

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Abstract: This work presents the TraxBot mobile robot design, a ground platform recently developed for applications in the mobile robotics field. The assembling of the robotic system, with description of its components as well as information about the microcontroller programming, development and testing are presented. The TraxBot is a multidisciplinary platform and is ideal for education, since it is easily programmed with open-source tools requiring basic knowledge of other areas beyond robotics, like mechanics, control or energy management. Although being released in a stable version, the robot is continually in development, with the ability to incorporate extensions to its design and new features.

1 INTRODUCTION

In recent years, a great deal of research on mobile robotics has been noticed. Several different robotic systems have emerged in order to assist or replace human operators mostly in tiring, repeating or time-consuming tasks. Earlier, the focus of research was especially on large and medium structures. However, with the advancement in sensor miniaturizations and the increasing in the speed and capability of microcontrollers in the past years, the emphasis shifted to the development of smaller, lower cost robots and experimentation with groups of robots.

In this paper, we present the design and implementation of a portable ground robot developed in the Mobile Robotics Laboratory (MRL) at the Institute of Systems and Robotics (ISR) in the University of Coimbra. The TraxBot is an ideal platform for education, since it can provide students with basics required to develop autonomous mobile robots, both at the hardware level (mechanics, energy, locomotion, embedded electronics, sensors) and software level (control theory, microcontroller programming, trajectory planning, localization). The setting up, development and programming of this robot was motivated by experimentation and research in cooperative multi-robot systems, more specifically teams of robots with distributed control to perform cooperative patrolling (Portugal and Rocha, 2010) and swarm foraging (Couceiro *et al.*, 2011) tasks.

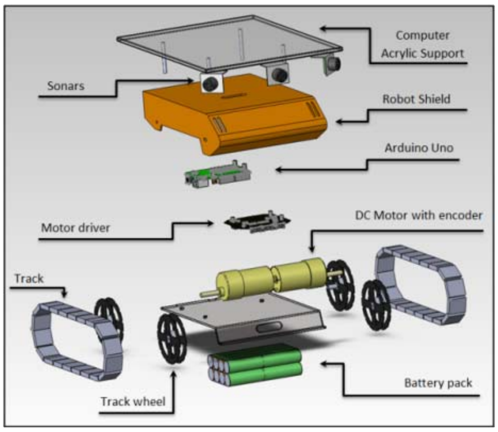


Figure 1: Mechanical structure of the TraxBot.

2 HARDWARE SPECIFICATION

The robotic platform in focus is a differential drive system built upon the Traxster II Robot educational Kit (Traxster II, 2008), equipped with 2 DC gear-head motors with quadrature wheel encoders. Rubber bands were attached to the original tracks to increase friction and reduce slip during locomotion.

The processing unit consists of an Arduino Uno board (Arduino Uno, 2010) equipped with a microcontroller ATmega 328p from Atmel, which controls the platform's motion through the use of the Bot'n Roll OMNI-3MD board (Bot'n roll, 2011).

For range sensing, the robot uses Maxbotix Sonars MB1300 with a maximum range of approximately 6 meters (Maxbotix, 2005), which can have a configurable disposition and the possibility of employing up to 4 sonars in one platform using the analog ports of the Arduino Uno board.

Additionally, to enable point-to-point communication, the Xbee Shield, consisting on a ZigBee communication antenna attached on top of the Arduino Uno board was also incorporated.

As for power source, two packs of 12V 2300mAh Ni-MH batteries are deployed under the chassis of each robot to ensure good autonomy.

Finally, the platform has the ability to include a 10” netbook on top of an acrylic support, extending the processing power and providing more flexibility. The netbook has the advantage of enabling communication via WiFi 802.11 b/g/n. In Figure 1, a 3D general view of the TraxBot assembly is presented.

Some hardware specifications are presented in Table 1. The choice of the robot design was made essentially due to the following reasons:

- Robustness: All hardware is either aluminum or stainless steel;
- Low Cost: The platform costs around 300€ (not considering the netbook);
- Operability: It has the ability to maneuver in many different types of terrain and surface topographies;
- Dimension: It is adequate for both indoor and outdoor experiments;
- Autonomy: It can operate continuously around 2-3 hours.
- Flexibility: It can incorporate many new extensions and components (e.g., LEDs, cameras, LIDARs, grippers, etc.).
- Hybrid design: It is able to work with and without a small netbook on top of the platform according to the user’s desire and applications.

Table 1: TraxBot Hardware Specifications.

Voltage Range [V]	9-14
Electric Current in Operation [mA]	1200
Electric Current in Standby [mA]	110
Maximum Speed [m/s]	0,95
Weight [g]	2045
Weight with netbook [g]	3160
Width [mm]	203
Length [mm]	229
Height [mm] with sonars	110
Height [mm] with netbook	155

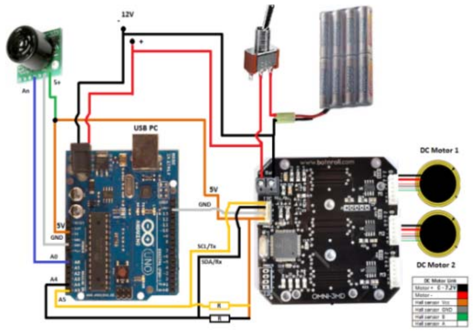


Figure 2: Main Electronic Circuit.

3 DEVELOPMENT

An outline of the electronics of the TraxBot platform is presented in Figure 2. The Arduino Uno board, the Bot’n Roll OMNI-3MD driver and the DC motors are located inside the robot shield, while the Maxbotix MB1300 sonar range finders are placed on top of the chassis. The battery packs are under the chassis and the circuit switch is located in the shield’s rear.

The batteries provide the energy source to the entire system. Having the Arduino Uno board as the central component of the system, a sonar range finder connects to it through the A0 port, receiving analog inputs from the sonar and reading voltage values. As for the connection to the Bot’n Roll motor driver, the ports A4 and A5 are used for Serial Data and Serial Clock Connection respectively.

The other three ports (A1-A3) of the Arduino Uno are available for integration of more sensors. The USB jack on the microcontroller connects to the netbook and is used to receive (RX) and transmit (TX) TTL serial data, which is decoded using a USB-to-TTL Serial chip in the microcontroller.

The motor driver is connected to the two DC Gearhead Motors through the encoder connectors.

The Bot’n Roll OMNI-3MD motor driver has the ability to control three motors in omnidirectional platforms by sending linear velocity, direction and speed commands, performing both velocity and position control. Furthermore, it has the flexibility to reset the parameters of PID control, reading encoders, measuring the battery voltage and monitoring the temperature of the board. The robot incorporates two DC motors with 624 pulses per output shaft revolution. Encoder information is read by the motor drive and provided to the Arduino Uno.

The Arduino Uno is an open-source hardware board based on the ATmega328 microcontroller, which provides serial communication. Its CPU runs at 16 MHz and provides 14 MIPS of peak processing power. An ATmega8U2 on the board channels the serial communication over USB and appears as a virtual COM port to software on the computer.

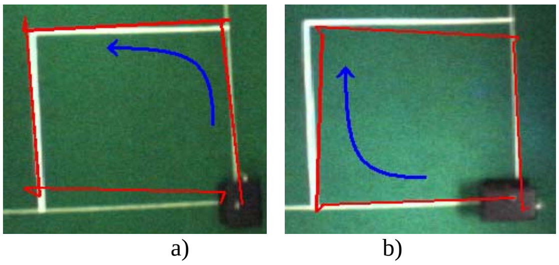
The open source Arduino environment is a powerful tool for education, in specific, microcontroller programming. In the current implementation, the robot has the ability to perform navigation commands, plan paths from an origin to a destination, perform self-localization based on its odometry and avoid obstacles in a reactive way using the sonars.

4 EXPERIMENTS

In order to evaluate the proposed platform, several tests were conducted on a lab scenario composed by a green and plain carpet with no flaws with a top mounted camera which recorded the experiments[1].

4.1 Odometry

The TraxBot was placed in the carpet with the objective to perform a square trajectory with one-meter of side length, in both clockwise (CW) and counter-clockwise (CCW) directions. This test is done to test its odometry, being extremely challenging due to the fact that the robot always turns in the same direction, and tending to accumulate dead reckoning errors without compensation in the opposite direction. Figure 3 illustrates the scenario and trajectories performed by the platform during the experiments. The trajectories illustrated were collected using an overhead camera mounted on top of the scenario.



a) b)

Figure 3: a) Odometry square test in CCW direction. b) Odometry square test in CW direction.

The tests were performed relying on the odometry system of the robot and without the assistance of any sensor or exterior localization information. As it is depicted in Figures 3.a) and 3.b), the robot performs movements in straight line with high accuracy, however finds it difficult to rotate exactly 90° as expected, with the error varying in different turns.

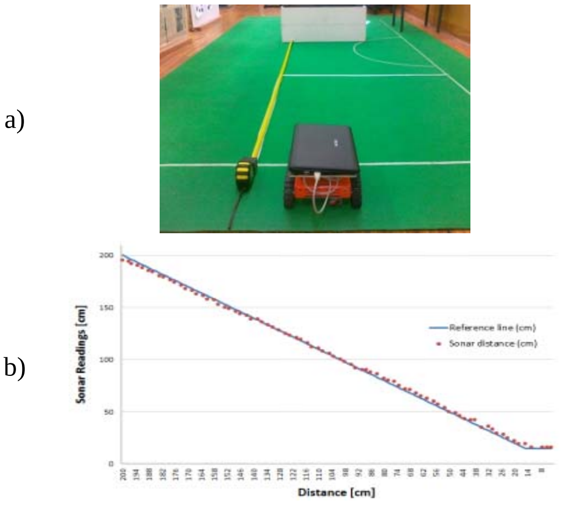
Besides, it is noticeable that, as it rotates around a fixed point, a minor slipping effect is present.

Nevertheless, the accumulated error in the end of each test, after one lap, is reduced. The trial in CCW direction ends with a positional difference of 9.67cm and an angle difference of -4.93° to the robot's initial pose; while in the CW direction the positional error is 7.71 cm and the angle difference is +2.13°.

4.2 Sensing Accuracy

In this test, a calibration phase was conducted to convert the analog output values given by the sonar readings to centimeters. By measuring sonar readings in a straight line at a distance to a wall between 5 to 200 cm, with an increment of 5 cm; a curve fitting power function $f(x)= a{\cdot}x^b+c$ converted the analog values data to centimeters.

In order to test the robustness of the calibration function and the sensing equipment, a simple test was conducted. As shown in Figure 4.a), the robot was placed two meters away from a regular obstacle and was driven in a straight line in its direction with a constant velocity of 0.14m/s. The robot stopped when it was 3 cm away from the obstacle. The sonar data was saved during the experiment.



a)

b)

Figure 4: a) Experimental scenario. b) Range testing results.

As seen in Figure 4.b), sonar readings are very close to the line of reference and can be used reliably to assist the robot's navigation. The average sonar measuring error was 1.83 cm, while the maximum error was 5 cm. These few observable errors have diverse sources, such as the limits imposed by

[1] A stable version of the Arduino code used to program the TraxBot and videos of all experiments are available at: http://paloma.isr.uc.pt/~aaraujo/TraxBot/

the sonar resolution, approximation errors caused by the calibration function, the manual measurement of 2 meters used in the experiment, and even the small errors that accumulate when the robot diverts while moving in a straight line.

4.3 Obstacle Avoidance

In the final test, an obstacle was added to the scenario. Programmed to navigate in a straight line from an initial configuration into an obstacle, the robot reactively avoids it using three sonars mounted below the acrylic support. After overcoming the obstacle, the robot replans its trajectory and drives to a final position. Figure 5 presents the trajectory of the robot during the experiment.

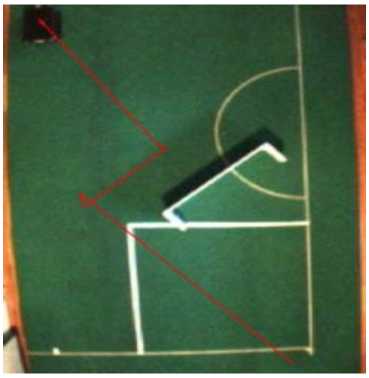


Figure 5: Overview of the reactive obstacle avoidance test. The red line denotes the robot trajectory in the experiment.

This test demonstrates that the robot is able to avoid obstacles and navigate safely in the environment. It decides in which direction it should rotate, while avoiding an obstacle through the composed readings of the three sonars. Note that some positional errors still propagate during the test due to its odometry system. Nevertheless, the robot is able to drive itself autonomously.

5 CONCLUSIONS

This paper presents the development and experimental evaluation of a robotic platform named TraxBot.

The TraxBot is suitable for enhancing basic programming skills, for exploring algorithms of interest to the robotics community and will also be useful in the fields of multi robot systems, since it is a cost-efficient, off-the-shelf solution. Furthermore, it takes advantage of the addition of computing power that a laptop can offer, since it allows the capability to extend its processing unit. Hence, the TraxBot offers both a realization of a practical autonomous robot and a novel resource that can be leveraged toward educational and research goals.

In the near future, the ZigBee module will be used to develop point-to-point communication with a team of TraxBots in cooperative multi-robot tasks. Moreover, in order to strengthen the robot's navigation, we intend to use the overhead cameras on our lab scenario for tracking and correcting robot's positions eventually with the assistance of RGB LEDs deployed on top of the robot. Finally, we intend to release a TraxBot driver for ROS (Quigley *et al.*, 2009), a popular robotic integration framework used in research laboratories and industry worldwide.

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