THE PATH TRACKER MOBILE ROBOT RMUT-1

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Abstract: This paper presents the design, construction and experimental results of an original mobile robot that tracks a pre-defined path marked with contrast colour on a plane surface. This type of mobile robots represents a simply and efficient experimental laboratory model to test various control methods and strategies. The two driving wheels are independently powered by DC electric motors, and the path tracking is accomplished using two optical sensors. The principles and design solutions for the mechanical, actuation and control systems, performances derived using experimental data and observations regarding project improvement and development are presented.

Keywords: wheeled mobile robot, optical tracking, differential drive control.

1. INTRODUCTION

Mobile robots represent a major component of the automated transport system that is part of the CIM concept. This research domain is a privileged and advanced one due to numerous high-level scientific papers, experiments that passed the laboratory phase and real solutions implemented in industry. In spite of this fact, the mobile robots, more or less autonomous, do not already represent a common presence, even in highly automated production plants.

Automatic guided vehicles represent a special category of mobile robots, used for inter-operational technological transport. This industrial system uses independently operated self-propelled vehicles that are guided along pre-defined pathways. In most cases, they are wheeled vehicles carrying the load pallet, powered by on-board rechargeable batteries and guided by sensors that track a pathway defined usually by embedded wire in floor or by contrast paint on the floor. The automatic tracking and positioning are performed by its own controller, which, lately, is designed to operate under the control of a supervisory computer system. The main industrial types of automatic guided vehicles are: the driverless train, the pallet truck and the automatic guided unit load carrier, [4].

Although the most attractive solution from the flexibility point of view is a completely autonomous mobile robot, an wheeled mobile robot with optical tracking a contrast coloured pre-defined path represents an economical candidate solution for solving automatic transport problems not only in industrial medium. For these reasons, the interest for designing and testing the control strategies of this kind of mobile robots emerges, [1, 2, 3]. The mobile robot RMUT-1, presented in this paper, represents a simply and efficient instrument to test various control methods and strategies for automatic guided vehicles.

2. ROBOT DESCRIPTION
The path tracker mobile robot RMUT-1 is an experimental laboratory model of a wheeled mobile robot with optical tracking the pre-defined path marked on a plane surface by contrast colour. The path may be marked with contrast coloured strip or contrast reflective paint.

Because it deals with a laboratory model, the design and construction of the RMUT-1 robot are as simply as possible. A light metal frame carries the mechanical, electrical and electronic control equipments as well as the electric batteries. The length, width and height of the whole construction are 180 mm, 145 mm and 120 mm respectively, while the total weight, including 2 batteries weighing 0.250 kg, is 1.2 kg.

The robot is equipped with two driving wheels mounted at 120 mm gauge and with a supplementary passive, unactuated, castor wheel mounted, for static equilibrium, at the rear median part. Each driving wheel, having a rubber wheel-rim of 40 mm diameter, is actuated independently by a DC electric motor with maximum 4,000 rpm rotation speed. The power is transmitted from motor to wheel through a gear transmission consisting from two cylindrical external gear pairs; the value of total transmission ratio is 24.

A single DC electric source is used to power both the electric drives and the control circuits. The robot is supplied with electric power either from a fixed DC 6-9 V feeder through long flexible cables or from batteries (4 x 1.5 V or 2 x 4.5 V, rechargeable or not) that are fixed on the robot frame. The total electric current consumption varies between 150 mA (unloaded running) and 200 mA (path tracking), approximately.

The robot control system consists of more functional sections interconnected as depicted in the block diagram in figure 1: sensory section, input stage, amplifier, inverter and power stage section.

![Figure 1 - RMUT-1 control system block diagram.](image)

The sensory section consists of 2 optical sensors that track the marked path, each sensor being composed of a pair transmitter / receiver. In order to diminish the influence of the environment illumination, optical sensors that work in the infrared (IR) domain were chosen. Actually, a red light-emitting diode (LED) is used as transmitter, while the receiver is an IR phototransistor. The quantity of IR rays received by the phototransistors, after reflection on the surface on which the path is marked, determines the magnitude of the electric current gained by each phototransistor. These electric signals are used, after corresponding processing, to command the actuating motors.

The input stage, having a high input impedance, adapts the phototransistors to the following electronic circuits and compares the voltages received from the two IR phototransistors. After amplifying, the generated electric signals of corresponding magnitude are sent to the actuating motors. An operational amplifier is used to reverse the electric signal to one of the electric motors. The power stage section amplifies the received, directly or through the inverter, electric signals in order to make possible the actuation of the electric motors.

All electric components used in the electronic circuit design (LED-s, phototransistors, operational circuits, transistors a.s.o.) are of general purpose use.

3. PATH TRACKING
The proportion between light rays reflection and absorption strongly depends on the colour of the encountered reflecting surface: mainly, the white colour surface reflects, while the black colour surface absorbs them. Because the colours of the marked path and its background absorb and reflect differently the infrared rays, the rays emitted by each LED are reflected or absorbed depending on the colour of the encountered reflecting surface. So, the corresponding IR phototransistor receives more or less reflected IR rays and consequently gains an electric signal of high or low magnitude. In this manner, the sensory section of the robot control system “distinguishes” the marked path and its background.

The above mentioned sections of the RMUT-1 control system electronic circuits process the electric signals received from the two IR phototransistors and command the rotation of the two actuation motors in order to track the marked path. Each motor rotates in only one sense, but the rotation speed varies from null to a maximum value, depending on the voltage of received electric command signal.

The RMUT-1 robot was designed and calibrated to track a pre-defined path marked with black colour on white background surface. The RMUT-1 control system permits, based on the same electronic circuits, but for different calibration values, a proper robot operation in two situations:
- the path width is larger than the distance between the two sensors;
- the path width is less than the distance between the two sensors.
In each case, the electronic circuits provide the following behaviours:
- when both optical sensors explore the black coloured surface of the path, the electric signals emitted by the two IR phototransistors generate quasi-equal speeds for the two actuating motors, so that, in ideal case, the robot tracks without deviation a straight-line path;
- when both optical sensors explore the white background surface or one of sensors explores the black path surface while another sensor explores the white background surface, the electric signals gained by the two IR phototransistors generate the acceleration of one actuating motor and a simultaneous deceleration of the other one, so that the robot deviates from a straight line trajectory and tries to return to the black marked path.

3. EXPERIMENTAL RESULTS

Because of experimental character of the RMUT-1 robot, all its functional parameters and calibration values were determined after numerous experiments concerning the path marking and dimensions, trajectory configuration, optical sensors positioning, supply voltage a.s.o. The main experimental results are:
- Although the IR radiation of the used red LED is weak and consequently the IR phototransistor works in the low region of its sensibility characteristic (visible-IR domain), the designed electronic circuits works properly.
- The experiments were performed without protecting the robot optical sensors against environment light rays; no noteworthy influence of the environment light on the path tracking was observed.
- The distance between the optical sensors and the rolling surface lies between 2.5-5 mm, the optimum value being 3 mm.
- The path / background colours couple used for path marking that provides a proper work of RMUT-1 robot ranges from grey to white background for a black colour path or grey to black background for a white colour path.
- For the used distance (7 mm) between the two optical sensors, the minimum width of the pre-defined path was determined to be 1.8 mm.
- The path tracking was tested on a complex plane trajectory (figure 2) including straight lines, curves and intersections. The minimum radius of the trajectory curved sections that are properly tracked by the RMUT-1 robot is about 100 mm. As regards the intersections, the path tracking is successfully if the value of the intersection angle of two trajectory parts is greater than 30°.
- For a complex trajectory having 3 loops and a total length of 4.5 m, the path tracking speed is:
  - 16.4 cm/s for 6 V supply voltage;
  - 19.1 cm/s for 7 V supply voltage;
  - 22.5 m/s for 8 V supply voltage.
For the third case, the path tracking is no more 100% successfully.
4. CONCLUSIONS

The RMUT-1 robot is a simple experimental laboratory model of an automatic guided wheeled vehicle with optical path tracking. It represents a useful, simply and efficient instrument for laboratory testing of sensor based mobile robot control elements, methods and strategies.

The performed experiments led to valuable conclusions in order to determine many constructive and functional parameters regarding contrast colours path marking, trajectory configuration, optical IR sensors construction and positioning and electronic circuits design and calibration.

It is intended to use the same wheeled vehicle to continue the study and research of mobile robot sensor based control strategies. As first step, the acoustical ultrasonic sensing of obstacle avoidance during the free way wandering will be tackled.

REFERENCES