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# MEASUREMENT METHODS FOR THE PATH DEVIATION OF MOBILE ROBOTS

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***Abstract:*** *Accuracy of mobile robots movement is vital to their orientation in the environment. Indoor mobile robots or automated guided mini-vehicles need accurate path tracking to avoid collisions with obstacles. In this paper are presented two methods for determining the deviation from the path, in order to eliminate errors that may occur due to imperfections of robot locomotion system. A method is based on measuring the linear deviation from path, using a route with bands of different sizes and colors. The other method determines the angular deviation using a device, with rotary motion sensor, mounted on a rail.*
***Keywords:*** *path deviation; mobile robots; locomotion system; ultrasonic sensor.*

## 1. INTRODUCTION

Locomotion is the process through the mobile robot moves in the environment with certain forces actuating on it [1]. Locomotion system has a crucial role in achieving the aim pursued in mobile robot function. It contributes to this both, embodiment of locomotion (wheel tracks, legs etc.) and structural aspects (degrees of mobility, orientation, maneuverability) of the variant admitted for the robot [2].
To determine the influence of the locomotion system in the workspace orientation were performed tests with mobile robots that moves using wheels, tracks and with walking robots. For measure the linear deviation from path it was use a route with bands of different sizes and colors, and for measure the angular deviation, it was use a device with rotary motion sensor, mounted on a rail.

## 2. MOBILE ROBOT USED FOR MEASUREMENTS

For the experimental study have been used six mobile robots presented in Fig. 1, namely: Pro Bot 128, Spy Video TRAKR, KSR4 - Escape, Maxibot, Hexbug Delta, and Remote-controlled mini-vehicle. Of those six mobile robots, depending on the locomotion system, three are wheeled, one tracked and two are walkers.
The Pro Bot 128 robot uses a wheeled differential locomotion system and has a high level of autonomy, having the possibility to sense and avoid obstacles with infrared sensors detection system, without the intervention of the human operator. For the navigation the robot was programmed to use its anti collision infrared sensorial system.
KSR4–Escape mobile robot uses a locomotion system with six wheels and for the navigation it is equipped with infrared detection sensors. The Escape Robot uses three infrared emitting diodes and one infrared receiving module to send and receive signals and detect obstacles.
The remote-controlled mini-vehicle uses for locomotion a four-wheel system with Ackermann steering type.
Spy Video TRAKR uses a tracked locomotion system, being a programmable robot, equipped with a color camera with infrared detection possibility, microphone and speaker. The robot can be controlled by remote control or can be programmed to travel along a selected route.

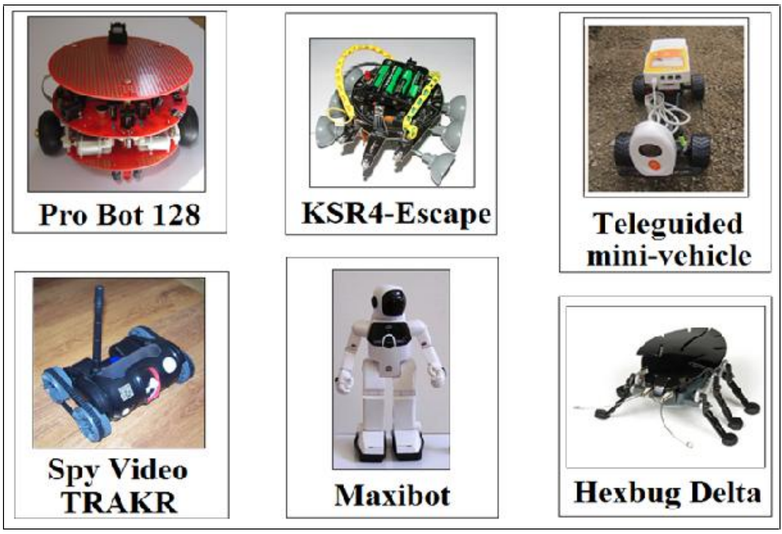


**Figure 1:** Mobile robots used at experimental research

Maxibot robot is a humanoid walking robot and for navigation uses an anti collision infrared sensorial system. The robot programming is performed using the program module located in the rear. This module has four keys and by pressing them it is determined how many steps are forward, backward, left or right.
Hexbug Delta is a walking robot that reacts to touch. His antennas are tactile sensors that modify the direction of travel to the touch. When the right antenna is touched, the robot turns to the right and left when the antenna is touched, the robot turns to the left. The robot is powered by the legs in the middle. The other four legs provide stability while driving. When the antennas are not reached, the direction of movement is forward.

## 3. DETERMINATION OF LINEAR DEVIATION FROM PATH

To determine the deviation from the path of mobile robots, it was set up a trail with bands of different sizes and colors like in Fig. 2. The narrow band, in the middle is green with width of 10 mm, left and right bands are yellow, with width of 15 mm, which are bordered by red bands with a width of 25 mm.

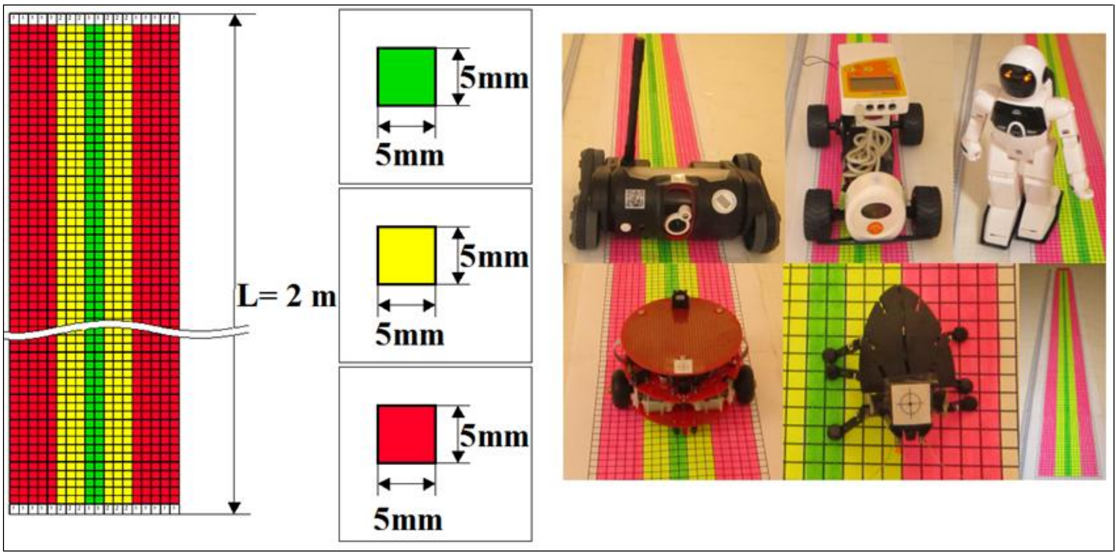


**Figure 2:** Trail chosen to determine the deviation from the trajectory

In order to determine the deviation from linear trajectory, each robot was separately measured and marked the center of symmetry like in Fig. 2.
The deviation from the straight path was determined by measuring the distance between the symmetry axis of the track and the center of each robot [3]. As long as the symmetry of each robot falls in the green band deviation is negligible, the measurement being made on yellow and red bands.

The robots displacement was filmed with a camera mounted on ceiling of the room where was arranged the workspace. Based on movie recording, has been determined accurately the linear deviation at every 200 mm of a total distance of 1800 mm (1.8m).
Table 1 shows the linear deviation values, determined for the six mobile robots.

**Table 1:** Linear deviation from the path

| Distance | Wheeled | | | Tracked | Walkers | |
|---|---|---|---|---|---|---|
| | Pro Bot 128 | Remote-controlled vehicle | KSR4-Escape | Spy Video TRAKR | Maxibot | Hexbug Delta |
| | Linear deviation | | | | | |
| d | $d_1$ | $d_2$ | $d_3$ | $d_4$ | $d_5$ | $d_6$ |
| [mm] | [mm] | [mm] | [mm] | [mm] | [mm] | [mm] |
| 200 | 3.2 | 4.2 | 5.2 | 2.8 | 5.5 | 5.8 |
| 400 | 6.1 | 8.8 | 11.1 | 5.3 | 10.1 | 12.3 |
| 600 | 8.5 | 12.2 | 15.8 | 7.2 | 18.2 | 22.2 |
| 800 | 11.7 | 15.1 | 23.6 | 9.8 | 24.5 | 28.9 |
| 1000 | 13.8 | 17.3 | 28.8 | 11.6 | 30.2 | 36.3 |
| 1200 | 15.9 | 20.2 | 32.3 | 13.9 | 38.8 | 48.2 |
| 1400 | 18.3 | 23.8 | 38.6 | 15.3 | 48.3 | 63.3 |
| 1600 | 21.3 | 26.1 | 45.8 | 17.6 | 63.2 | 82.2 |
| 1800 | 22.2 | 28.6 | 52.3 | 19.1 | 91.3 | 112.1 |

Fig. 3 presents the variation of linear deviation from the path based on the distance traveled. It is noted that robots Pro Bot 128, Remote-controlled vehicle and Spy Video TRAKR deviation increased linearly with the distance. At walking robots it is noted that the deviation values increased exponentially to the distance traveled [4].

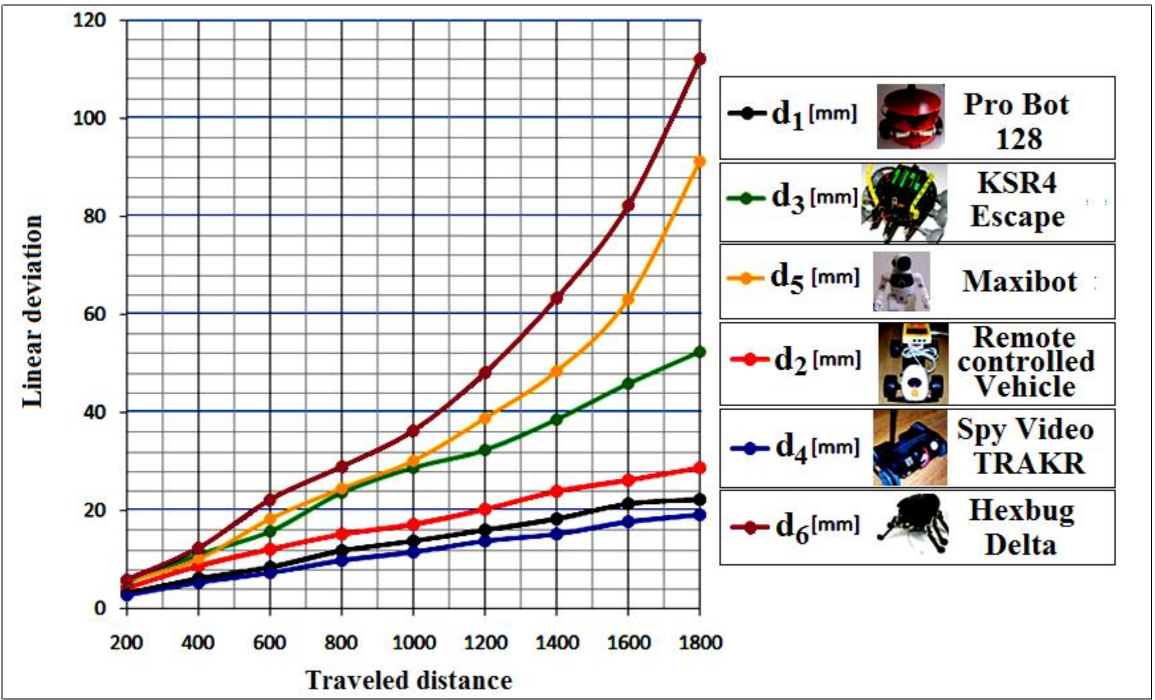


**Figure 3:** Linear deviation for the six mobile robots

Fig. 4 shows the distance traveled of all six mobile robots, on the three different color bands. It is noted that the robot Spy Video TRAKR traveled the greatest distance to the green and was the only one who did not passed on red band. Delta Hexbug walking robot has traveled the shortest distance on the green and the biggest distance on red.

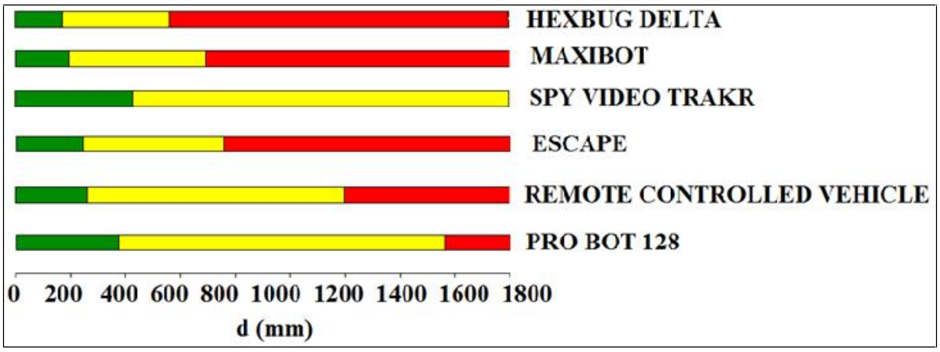


**Figure 4:** Distance traveled on the bands of different colors

## 4. DETERMINATION OF ANGULAR DEVIATION FROM PATH

In order to determine angular deviation from the path has been designed a device that runs on rails and incorporates a sensor that measures the angular deviation [5].

The sensor mounted on the device is connected to the tested robot and to the data acquisition system MultiLogPRO witch provide real-time readings. The device movement will be rectilinear and friction between the wheels and the two rails will be minimized.

The used rotary motion sensor, DT148A monitors the angular position and indicates the direction of travel, having positive or negative values. Measuring the amount of angle deviation from the path, the sign is irrelevant. Sensors accuracy is $0.125^o$ with a sampling rate of 10 samples per second. For data acquisition it was used a MultiLogPRO system. The MultiLogPRO system is a standalone 12-bit data logger with a clear LCD graphic display and a 128K internal memory. Recorded data are displayed in the form of graphs, tables, meters or digital displays, and can be analyzed with a number of pre-programmed analysis functions. This system internal memory stores experiment notes and instructions for carrying out the experiment, which can be edited or expanded at any time. MultiLogPRO can record data from up to 8 sensors simultaneously and it's capable of recording at rates of up to 21000 samples per second, and of collecting up to 100000 samples in its internal memory [6].

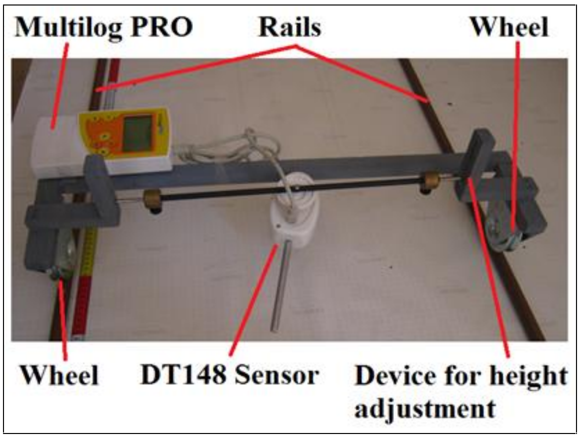


**Figure 5:** System for determining the angular deviation

In Fig. 5 it is presented the whole system obtained to determine the angular deviation at robots movement. With that system were tested the robots Spy Video TRAKR (tracked), Pro Bot 128 (wheels), Remote-controlled vehicle (wheels) and Maxibot (walking), like in Fig. 6. The sensor was attached to each robot in part with a fixed grip.

**Figure 6:** System used connected to the mobile robots

Table 2 presents the values obtained from the measurements performed with the device. Values of the measured angles were recorded from 200 to 200 mm, over a distance of 1.8 m.

**Table 2:** Linear deviation from the path

| Traveled distance | Wheeled | | Tracked | Walker |
|---|---|---|---|---|
| | Pro Bot 128 | Remote vehicle | Spy Video TRAKR | Maxibot |
| | Angular deviation | | | |
| d | $\beta_1$ | $\beta_2$ | $\beta_3$ | $\beta_4$ |
| [mm] | degrees | degrees | degrees | degrees |
| 200 | 0.92 | 1.20 | 0.80 | 1.58 |
| 400 | 1.75 | 2.52 | 1.52 | 2.89 |
| 600 | 2.43 | 3.49 | 2.06 | 5.20 |
| 800 | 3.35 | 4.32 | 2.81 | 6.98 |
| 1000 | 3.95 | 4.94 | 3.32 | 8.59 |
| 1200 | 4.54 | 5.77 | 3.98 | 10.98 |
| 1400 | 5.23 | 6.79 | 4.37 | 13.58 |
| 1600 | 6.08 | 7.44 | 5.03 | 17.54 |
| 1800 | 6.33 | 8.14 | 5.46 | 24.54 |

After the data analysis, we can say that the values obtained for Maxibot walking robot are different from values obtained for the others robots. The angular deviation from the path is greater in comparison with the deviations determined for the other robots and is showed in Fig.7.

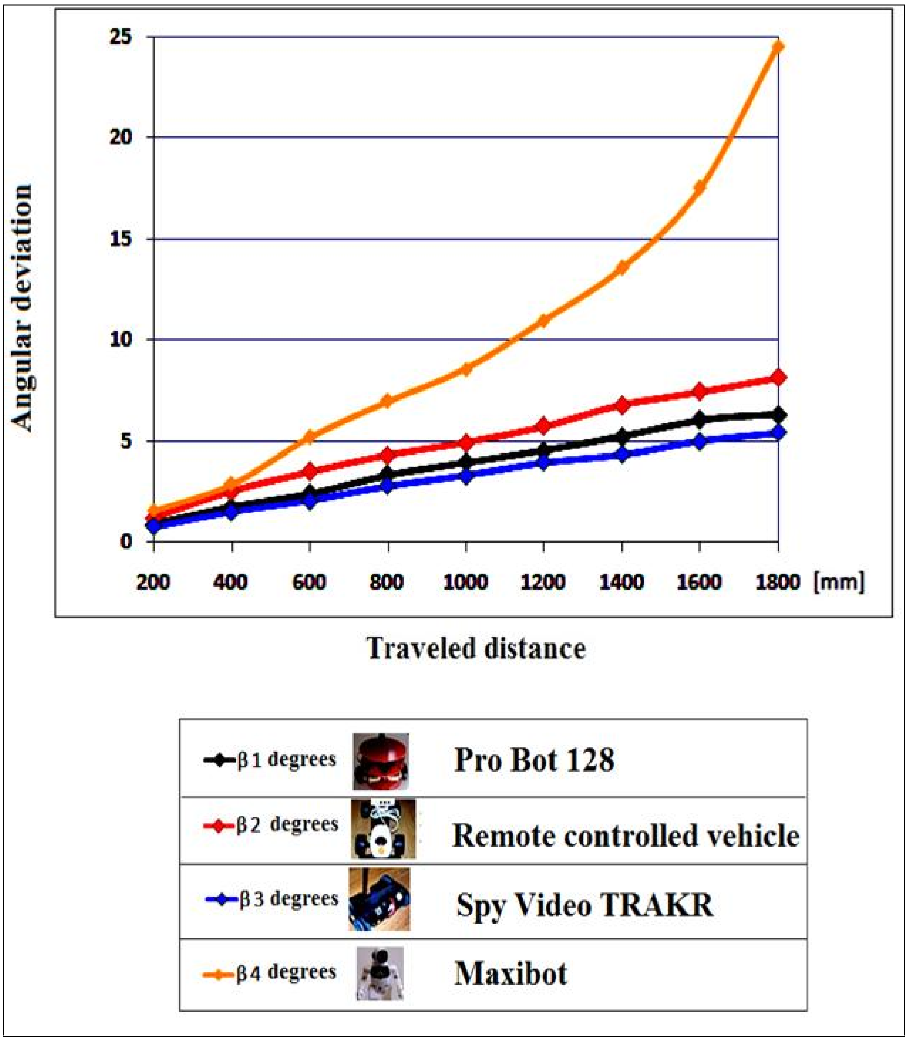


**Figure 7:** Angular deviation for the tested robots

## 5. CONCLUSION

In terms of deviation from the path, the largest differences were obtained with walking robots Maxibot and Hexbug Delta.

To correct the way that travels the Maxibot walking robot, will be set like that: after four steps forward, the robot shall be made one step to the left. This will correct its trajectory, the robot initially having a tendency to move to the left.

At Hexbug Delta, if the robot, during movement tends to turn left, then the left leg position will be adjusted, and if it tends to turn right, then right leg position will be adjusted. The steps to cancel the malfunction are [7]: determine the leg that must be adjusted; supports the robot so that adjustment can be made as simple as possible; adjust the leg position from its pivoting point.

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