Simulation of a ride of the real mobile robot according to the defined path

WILK Piotr 1,a, ZAJĄC Tomasz 1,b, PAŚNIKOWSKA Anita 1,c, CEKUS Dawid 1,d
1 Faculty of Mechanical Engineering and Computer Science, Częstochowa University of Technology, ul. Dąbrowskiego 69, 42-201 Częstochowa, Poland
a wilcus291@wp.pl, b tomasz.zajc@gmail.com, c anita.pasnikowska@gmail.com, d cekus@imipkm.pcz.pl

Keywords: Catia, control, mobile robot, simulation

Abstract

In the paper formulation of a method that enables a race of real mobile robot according to a path defined in Catia program has been presented. On the basis of performed simulation, parameters, necessary for the task realization, have been obtained and collected into a matrix, and then they have been imported and implemented into the mobile robot. Exemplary experimental research for P, PI and PID regulators with the turbine switched off and for P regulator with the turbine switched on, have been carried out.

1. Introduction

Within the framework of the presented paper, formulation of a method, that enables a mobile robot to race according to path defined in Catia program, has been presented. The following problem has been divided into several stages. Firstly, a skeleton of the robot has been modeled in Catia program. Secondly, a path, which consists of a number of tangents to one another line segments and arcs, has been created. Then, the simulation of the robot racing along the defined path has been performed and readings of displacement parameters of the left and the right wheel have been taken and collected into a table. Values obtained in this way have been imported and implemented into real object, that is, a mobile robot. Finally, experimental researches have been carried out and the race accuracy has been derived.

2. Simulation model

In the paper, to determine the track and to carry out the simulation with a set velocity of the mobile robot, a Catia [1] software package has been exploited. Catia is the multipurpose tool that aids engineering tasks, especially used by automotive and airline industries.

With the aim of conducting the simulation the skeleton of the robot has been created. This simplification has allowed to significantly shorten the time needed for the model preparation and at the same time has not had an influence on the accuracy of obtained numerical results. Individual elements of the robot have been modeled in Part Design module, and then in Assembly Design module the assembly of them has been done. The racing track, which has been created in the form of the sketch, that consists of a number of segments, which ends are tangent to one another, has been added to the robot assembly. It is possible to determine any racing track in Catia program, however it is necessary to take into consideration the limitations which result from the construction of the robot and control program. Model of the robot has been connected with the set racing track by means of kinematic joints predetermined in DMU Kinematics [2] module. Simultaneously, it makes possible to create a mechanism, which enables the simulation race of the robot along the defined racing track (Fig. 1). A necessary condition to carry out the simulation is to set the value of the velocity parameter, which is a linear velocity of the displacement along the track. The velocity is a mean value of the rotational speed of the engines. For a straight-line segment of the track the
speeds of the engines are to be equal to each other, however, in case of racing along curvilinear track the values of the speeds are to be different, depending upon curvature of the racing track.

Fig. 1. The simulation model with the sample results of simulation

On the basis of the simulation the angular displacement, which has been raced by the left and right wheel, has been derived. The information has been collected every 0.02s. Such a time step is sufficient for the real object to perform a correct racing track.

3. Research object

The mobile robot [3], which has been built within the framework of Scientific Society of Computer Aided Design of Mechatronic Devices and Machines (Fig. 2), has been exploited for the experimental research.

The construction of the robot is founded on the Printed Circuit Board (PCB) (1), and main control unit is the AVR microcontroller – ATmega644P (2) [4]. The robot is propelled by the two DC micro engines with the gear 30:1 (3). In the front of the construction the spherical support (4), which is third fulcrum of the robot, is mounted. The controlling of the engines is performed indirectly by the H bridge [5]. Additionally, the robot is equipped with a special turbine (5) which generates underpressure that increases tractive adhesion. The turbine consists of the brushless engine with a dedicated controller, a rotor and a profiled tunnel. For a raced distance measurement, optical encoders (6), which have been made on the basis of optocoupler TCST 1103 cooperating with discs that have 36 black fields painted, have been used. Optocouplers are one channel, incremental encoders which measure the increase of the angular path. The application of the one channel encoders results in an inability of the determination of a direction of the engine rotation in a direct way. The discs are mounted to the rims with the use of the special quills. For rotating wheels, the cyclical interruption in the light flow occurs between a photodiode and a phototransistor, what comes down to the signal generation by the encoder in the form of the rectangular wave at the exit. The incrementing of the raced path counter occurs for rising and trailing edge of signal, what enables to achieve the resolution of 72 impulses per one rotation of the wheel.
4. Control program

Main control program with the racing track is stored on the microcontroller ATmega644P. Before the entering of the track created in Catia program into the microcontroller memory it is necessary to change the obtained angular path into the linear path. The track is saved in the form of two dimensional table, in the first column of the table the path of the left wheel is written, in the second column of the right wheel respectively. Time occurs in the secret form as an index of the table element number.

In the program three interrupt functions occur [6, 7]:
- first of them is responsible for racing track definition. With the proper time step, the readings, of the expected value of the path ascribed with the set time, are taken. This function is initialized 50 times per second,
- second one is in charge of the regulator work. Defined values of the paths for both wheels are compared with the raced distance, the difference of these values gets entrance as a control error. Then, in the PID regulator [8] the values of corrective impulses are counted. The frequency of switching on can be changed programmatically,
- last interrupt function is responsible for the encoders operation. This function is activated on the rising and trailing edge of the signal. After initialization of that, the incrementing of the counters that sum up the raced distance, occurs.

Since the robot is connected to the current source it expects for the START button to be pressed, then it waits one second and after that, the flag alignment is done, which switches on the interrupt functions service. Further action of the program is held inside of the interrupt functions. The change of the value of the path takes place 50 times per second, the regulator intervenes couple times more often and compares the raced distance with the reference value. After covering the set path, flag, which allows to service of interrupt functions, is erased and engines stop.

5. Results

The exemplary, experimental researches have been carried out on the track which reflects the track made in Catia program. The analyzed track consists of five segments and is shown in Figure 3.
Fig. 3. The analyzed track: a) sketch from Catia program, b) real object

Results of the research have been divided into four measurement blocks: for the P, PI and PID regulator with the turbine switched off, and for the P regulator with the turbine switched on. The frequency of the regulator intervention has been constant and equal to 1 kHz. In each case, 30 measurement racings have been performed.

The measurement have been consisted in defining the distance between a place where the robot has stopped and the origin of the XY coordinate system which has been set at the point where the end of the track, that is, where the robot should have been stopped. The research results are presented in Figure 4.

Fig. 4. Results of experimental investigations: a) measurement with the P regulator (proportional term = 500) and turbine on and off, b) measurement with the PI (proportional term = 500; integral term = 75) and PID (proportional term = 500; integral term = 75; derivative term = 1000) regulator

On the basis of obtained experimental studies, statistical analysis has been carried out and following values have been determined [9]:

- arithmetic mean:
\[
\bar{x} = \frac{1}{n} \sum_{i=1}^{n} x_i
\]  

(1)

- value of the module of arithmetic mean:

\[
z = \sqrt{x^2 + y^2}
\]  

(2)

- standard deviation:

\[
s = \sqrt{\frac{1}{n} \sum_{i=1}^{n} (x_i - \bar{x})^2}
\]  

(3)

- typical variable field, determining the interval of appearance of the value:

\[
\bar{x} - s < x_{op} < \bar{x} + s
\]  

(4)

- median.

Obtained results have been put together in Table 1.

### Table 1. Statistical analysis

<table>
<thead>
<tr>
<th>Controller type</th>
<th>P</th>
<th>PI</th>
<th>PID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbine</td>
<td>Off</td>
<td>On</td>
<td>Off</td>
</tr>
<tr>
<td>Coordinate</td>
<td>x</td>
<td>y</td>
<td>x</td>
</tr>
<tr>
<td>Average [mm]</td>
<td>-80,1</td>
<td>31,4</td>
<td>-43,1</td>
</tr>
<tr>
<td>Average module [mm]</td>
<td>105,1</td>
<td>78,4</td>
<td>102,6</td>
</tr>
<tr>
<td>Standard deviation [mm]</td>
<td>69,2</td>
<td>52</td>
<td>60,8</td>
</tr>
<tr>
<td>Typical variable field [mm]</td>
<td>-149,3</td>
<td>-20,5</td>
<td>-103,9</td>
</tr>
<tr>
<td>Median [mm]</td>
<td>-94,5</td>
<td>25</td>
<td>-43</td>
</tr>
</tbody>
</table>

On the basis of conducted experimental tests and statistical analysis one has been able to state, that:

- measurement racings for the P regulator with the turbine on have been marked by the best accuracy, both for x and y coordinates. However, the turbine running significantly increases power consumption, what shorten the action time from 40 minutes to 3 minutes,
- with the turbine off the best accuracy is characterized by the action of the PID regulator program. Regulators P and PI have similar level of accuracy, however PI regulator shows considerably better concentration of measurement points.

### 6. Summary

In the project the method that enables a mobile robot to race according to path defined in Catia program has been presented. Wheels location parameters have been read on the basis of the simulation made in Catia program, then they have been exported in the form of the table to the microcontroller which controls the robot running. In the analyzed case the size of the trace has been
limited by the memory capacity of the ATmega644P microcontroller, it has been possible to enter maximally 2000 values on the table.

Exemplary experimental research for P, PI and PID regulators with the turbine switched off and for P regulator with the turbine switched on, have been carried out. On the basis of the obtained results it has been stated that the best accuracy of the racing is marked by the action of the PID regulator. The slip of the wheels, surface roughness, imprecise readings from microcontrollers and irregular motors running could influence on the race inaccuracy.

Presented method, on account of simplicity of a definition of an arbitrary track in Catia program together with the velocity setting, which can be changeable through the time, may find an application in places where an often change of a track of autonomous robots running is required.

Acknowledgment

The study has been carried out within research of Scientific Society of Computer Aided Design of Mechatronics Devices and Machines. The publication is founded by Project POKL.04.01.02-00-218/11-00 “Nowoczesny inżynier przyszłości naszej gospodarki - atrakcyjne studia na kierunkach zamawianych” co-founded by UE means as a part of EFS.

References