Mechanics and Mechanical Engineering
Vol. 10, No 1 (2006) 40–55

Mechatronics of wheel minirobot *M.R.K*

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Received (15 May 2006)
Revised (27 May 2006)
Accepted (18 June 2006)

In this paper some problems concerned with designed and made by author's mini robot named *M.R.K* are explained. Most important think is modeling of kinematics and dynamics of such type of mechanism. Example of use of fast prototyping methods for implementing models in robot control system was shown. Problem of modeling of kinematics was explained together with effects of simulations. In case of modeling of dynamics to basic configurations of robot, with and without of supporting wheel are discussed. Control system of robot was made with use *InTouch*, *Matlab* and *MS SQL* database engine, visualization system was applied to help controlling robot in unknown or uncertain work space.

Keywords: Construction, kinematics, dynamics, simulations, control system

1. Introduction

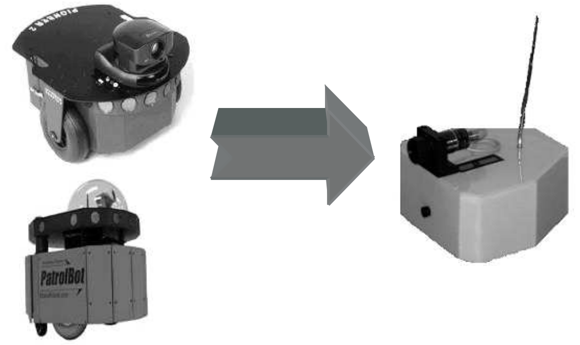
The mobile minirobot *M.R.K* is a device aimed to work in laboratory conditions. Analyzing riding properties and autonomous programming it will be possible to get close look at behaviour of mobile minirobots in working space; and, thanks to installed sensors also orientation in an unknown area for example: penetration of new rooms, locating damages in water-sewage systems etc. The model is one of the examples of mobile minirobot construction. The MRM model was built on the assumption that it will be a flexible and module construction enabling rapid changes in configuration, number of sensors and attachments of new components.

Initially the Handy Board microcontroller made by Massachusetts Institute of Technology was used for the construction, it is device minirobot oriented, but due to limited extension it was abandoned. Currently the robot is equipped with PLC UAL 004 controller by GE Fanuc company. Additionally a new steering M.R.K.

element was applied, which is a visualization of the behavior in the working spaces and readout of movement parameters on-line. Visualization is based on SCADA InTouch program, plus extra communication modules. The communication of the *M.R.K* witch PC is carried trough wi-fi by radiomodems.

2. *M.R.K* construction

Mobile minirobot construction based on PIONIER 2 DX mobile minirobot and other designs of similar type [1,2,6,8]. The authors decided to chose this construction as the most universal and most often used in the industry. *M.R.K*was designed mainly



for research and didactic. Reasons and the components applied allow possibility of extension and configurations change which makes the model universal.

2.1. *M.R.K* ***project***

The first step of the construction was the chose of a suitable model. The object was designed in *AutoCad* program and analysis was of the construction was of the construction was carried out with the use if graphic-simulation programmes.

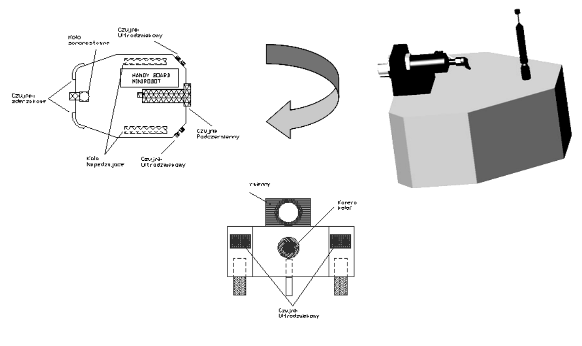


Figure 1 Project of mobile minirobot - *M.R.K*

The simulation of designer construction helped the authors to improve the project short coming and enabled the *M.R.K* movement monitoring.

The *M.R.K* was built of very light and also distortion – resistant materials: the frame and the platform are made of plastic reinforced with additional beavers. This

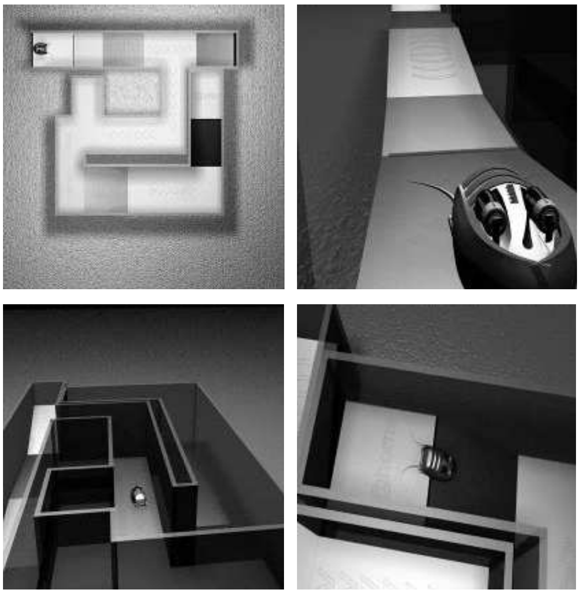


Figure 2 Simulation of designer construction

group of materials was decided upon by taking into consideration the fact that the batteries used as the power supply are rather heavy and considerably influence the dynamics of the whole system.

2.2. *Constructional assumptions*

As it was necessary to chose a suitable model [1,2,3,4,5,6,8] the following solution was proposed:

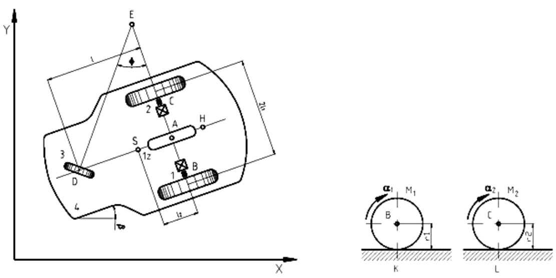


Figure 3 Scheme of construction mobile minirobot

Where:
$m_1 = m_2 = 0.053[kg]$ – substitute mass of wheels 1 and 2,
$m_3 = 0.025[kg]$ – substitute mass of wheel 3,
$m_4 = 0.565[kg]$ – substitute mass of the frame,
$I_{X1} = I_{X2}0.000024[kgm^2]$ – substitute mass inertia moments of wheels 1 and 2

relative to the axes x_1 and x_2,
$I_{Z1} = I_{Z2} = 0.00028[kgm^2]$– substitute mass inertia moments of the adequate wheels relative to the axes of self-turn of the wheel, it was assumed that the axes of reference system connected with part i are that main central axes of,
$N_1 = N_2 = 1.04[N]$, $N_3 = 0.9[N]$ – are the loads forces of the wheels 1, 2 and 3,
$f_1 = f_2 = 0.01$, $f_3 = 0.005$ – are rolling friction coefficients of adequate wheels, M_1 and M_2 steering moments wheels 1 and 2,
$l = 0.075[m]$, $l_1 = 0.07[m]$, $l_2 = 0.01[m]$, $h_1 = r_1 l_1^{-1}$ are adequate distances which result from the geometry of the system,
$r_1 = r_2 = r = 0.03[m]$, $r_3 = 0.015[m]$ – are radiuses of adequate wheels.

2.3. *M.R.K* ***range and manoeuvrability***

The minirobot is a laboratory device there fore research is being carried out to maximize its range. At present the only limitation is the reach of the radiomodem and visual transmission system (up to 100m – open space, 30m – confined space). The constructors intension is application of GPS and UMTS systems, allowing the possibility of unlimited location and control.

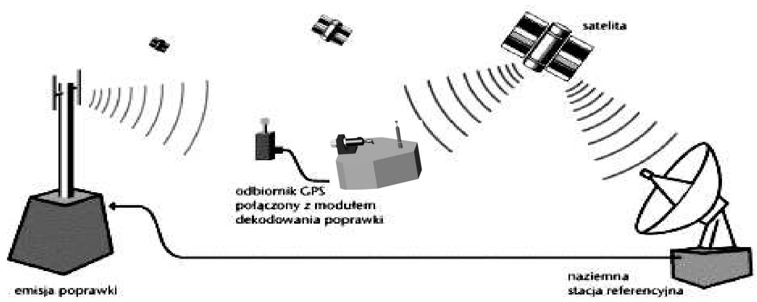


Figure 4 Conceptional project of steering *M.R.K* from utilization location GPS

Currently, the accuracy of a GPS system is very high (to a few centimetres) and is systematically increasing. There fore, this solution in controlling robots should be considered. The potential of GPS is almost unlimited, even the simplest system provide such parameters as location, speed, high and time.

The mobile minirobot's manoeuvrability is limited only due to applied configuration and the chosen model. The maximum speed for the built construction is $0.03m/s$, and the turning radius is shown below [3,4]:

MICRO MOTORS engines, used as the drives, enable the minirobot to drive uphill at the angle of 40°.

3. Mobile minirobot kinematics and dynamics modelling

3.1. ***KINEMATICS***

The model shown in fig 3 was adapted to describe the kinematics of 2-wheel M.R.K. Kinematics equations were used for distinctive points of the robot and it was assumed that it moves with a constant velocity of point A. (V$_A$)

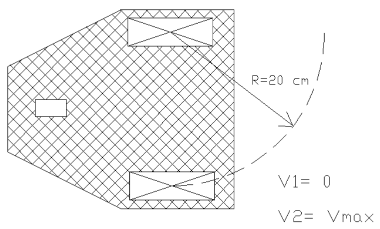


Figure 5 Turning radius when $V_1 = 0$ and $V_2 = V_{max}$

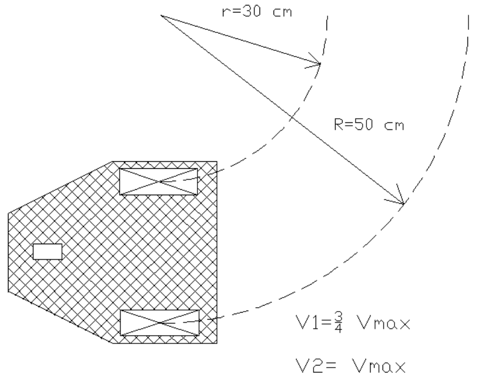


Figure 6 Turning radius when $V_1 = 3/4\ V_max$ and $V_2 = V_{max}$

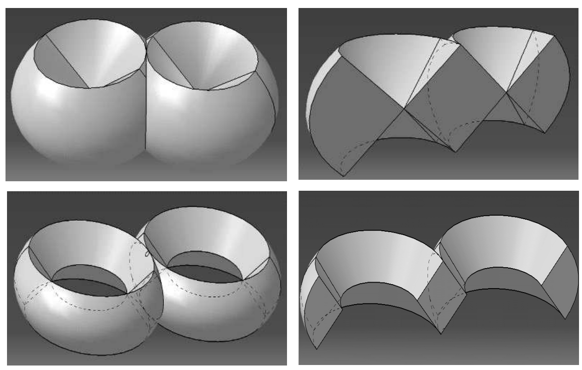


Figure 7 *M.R.K* workspace

To present the operation of motion parameters a reserve kinematics problem was modeled (*A reserve kinematics problem consists defining kinematics motion parameters knowing the position and the robot's spatial orientating*) [1,2,4,5,6].

The following set of equations determines the velocity vector projection for the tangency points of wheels and the road surface onto the x-axis.

$$\begin{aligned} \dot{x}_A - r_1\dot{\alpha}_1\cos(\beta) + l_1\dot{\beta}\cos(\beta) = 0 \\ \dot{x}_A - r_2\dot{\alpha}_2\cos(\beta) - l_1\dot{\beta}\cos(\beta) = 0 \end{aligned} \tag{1}$$

$$\sqrt{l_5^2\dot{\beta}^2 + v_A^2} - r_3\dot{\alpha}_3 = 0 \tag{2}$$

The equations (1) allow to determine motion linear parameters of a mobile 2-wheel robot such as: route, speed or acceleration as well as motion angular parameters like: rotation angles, angular velocity, angular acceleration, thus enabling to solve kinematics simple and reverse problems. The knowledge of a mobile 2-weel robot's motion kinematics parameters is the basis for solving dynamics reverse problems. Additionally in order to determine kinematics parameters of the self adjusting supporting wheel, a relation resulting from factorization velocity of the models distinctive point was illustrated.

When controlling mobile vehicles the problem of reverse kinematics should be considered. Based on the equations (1), (2) the simulation were carried out using the MATLAB$^{\text{TM}}$/Simulink package, and the following route was implemented: start-up, straight line drive, left turn, straight line drive, right turn, straight line drive, barking.

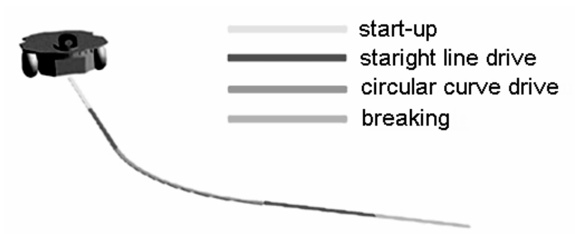


Figure 8 Analysed *M.R.K* motion trajectory

Characteristic of individual kinematics parameters are shown below:

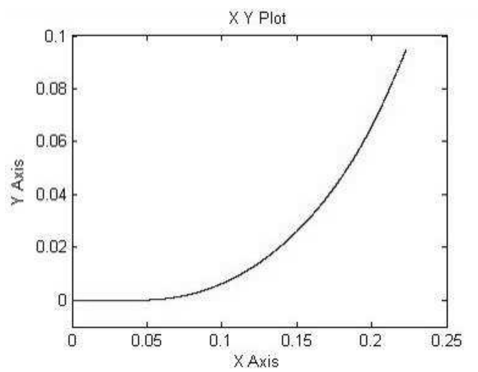


Figure 9 Point H trajectory

Analysing the above characteristics it can be noticed that the self-adjusting wheel can considerably affect the dynamic system, therefore it should be taken into consideration in further control and construction analysis process.

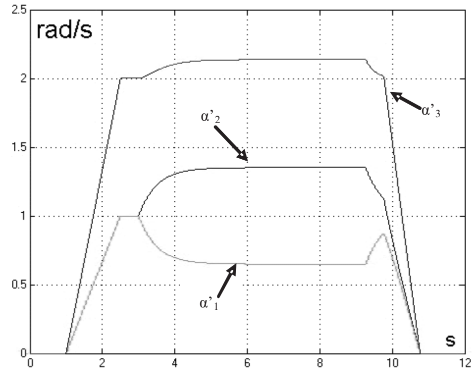


Figure 10 Driving wheels velocity $\alpha_1' \; \alpha_2' \; \alpha_3'$

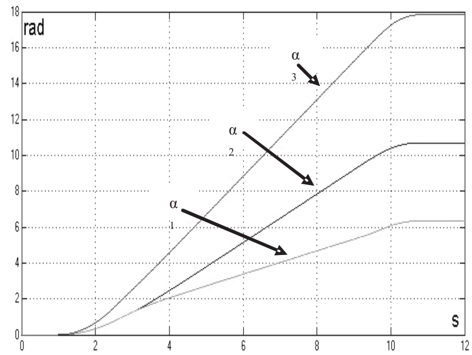


Figure 11 Driving wheels relocation $\alpha_1 \; \alpha_2 \; \alpha_3$

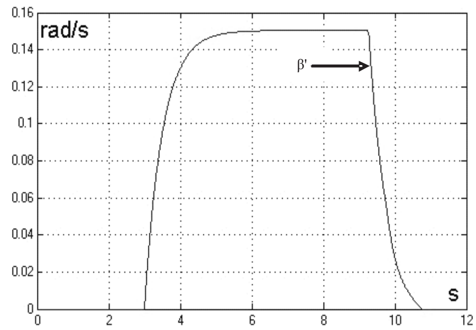


Figure 12 Framework angular velocity β

Characteristic in fig. 10 and 11 demonstrate individual wheels operation during the drive, 3 stage can be dishing wished here: the same angular velocity drive, velocity change for individual wheels and finally, return to equal velocity for wheels

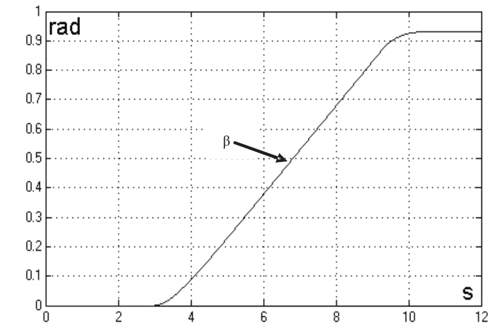


Figure 13 Framework relocation β

1 and 2. The characteristic illustrating velocity and relocation β shows dependence of the framework an the individual driving wheels velocity.

Obtained kinematics parameters will be used for dynamics analysis as well as controlling the mobile minitobot.

3.2. *DYNAMICS*

Dynamics equations of mobile robot motion can be used for solving simple and reverse dynamics problem [1,2,3,4,6,8]. In a simple problems it is possible to determine parameters connected with motion, in a reverse problem – force and moment affecting the robot.

To analyse the dynamics and illustrate minirobot operation a reverse dynamics problem was solved. The minirobot moves in 1 plane and its location requires providing point A – x_A, y_A coordinates, momentary turn angle β of the framework, the driving wheel turn angle α, and self-adjusting wheel turn angle α_3.

The Maggie's equations application enables omitting the procedures decoupling multipliers from drive moments, as the number of generalized coordinates in Maggie's equations the quantity of degrees of freedom. This if one is interested in drive moments, it is advisable to use Maggie's equations as fallow:

$$\sum_{j=1}^{n} C_{ij}\left[\frac{d}{dt}\left(\frac{\partial E}{\partial \dot{q}_j}\right)-\left(\frac{\partial E}{\partial q_j}\right)\right]=\Theta_i \tag{3}$$

where s determines the number of unrelated system parameters in generalized coordinates.

$$\dot{q}_j=\sum_{i=1}^{s} C_{ij}\dot{e}_i+G_j \tag{4}$$

q_j *(j=1..n)* in the number equal to quantity of degrees of freedom.

The above equations taking into consideration the supporting wheel, was solved in MAPLE$^{\mathrm{TM}}$ programme.

Maggie's equations for 2-wheel mobile robot model were previously presented in the literature [1,2]. Extending calculation model and taking into account the self-adjusting supporting wheel mass, Maggie's equations in a very complex form were received:

$$
\begin{aligned}
& r^2(2m_3l_1^2\ddot{\alpha}_1 + m_4l_1^2r\dot{\alpha}_2 + m_3l_5r\dot{\alpha}_2^2 - (2m_3l_5r + 2m_4l_2r)\dot{\alpha}_1\dot{\alpha}_2 + m_3l_5r\dot{\alpha}_1^2 + \\
& 2m_4l_1^2\ddot{\alpha}_2 + 2m_4l_1^2\ddot{\alpha}_1 + 2m_3l_1^2\ddot{\alpha}_2 + 4m_2l_1^2\ddot{\alpha}_2 + m_4l_2r\dot{\alpha}_1^2)/8l_1^2 + \\
& +\tfrac{r}{2}(((m_1 - m_2)\cos(\tfrac{r(\alpha_1-\alpha_2)}{2l_1})l_1 + (m_4l_2 + m_3l_5)\sin(\tfrac{r(\alpha_1-\alpha_2)}{2l_1})) \\
& (\tfrac{1}{2}(\ddot{\alpha}_1 + \ddot{\alpha}_2)\cos(\tfrac{r(\alpha_1-\alpha_2)}{2l_1})r + \tfrac{(\alpha_2^2-\alpha_1^2)\sin(\frac{r(\alpha_1-\alpha_2)}{2l_1})r^2}{4l_1}) + \\
& +((m_1 - m_2)\sin(\tfrac{r(\alpha_1-\alpha_2)}{2l_1})l_1 - (m_4l_2 + m_3l_5)\cos(\tfrac{r(\alpha_1-\alpha_2)}{2l_1})) \\
& (\tfrac{1}{2}(\ddot{\alpha}_1 + \ddot{\alpha}_2)\sin(\tfrac{r(\alpha_1-\alpha_2)}{2l_1})r + \tfrac{(\alpha_1^2-\alpha_2^2)\cos(\frac{r(\alpha_1-\alpha_2)}{2l_1})r^2}{4l_1}) + \\
l\ & +\tfrac{1}{2l_1}(Ix_1 + m_2l_1^2 + Iz_4 + Ix_3 + m_4l_2^2 + Ix_2 + m_1l_1^2 + m_3l_5^2 + \tfrac{Iz_3l_1^2}{r_3^2} - \\
& \tfrac{6Ix_3l_1^2r^2(\dot{\alpha}_1-\dot{\alpha}_2)^2v_A^2}{4(v_A^2+\frac{r^2}{4}(\dot{\alpha}_1-\dot{\alpha}_2)^2)^3} + \tfrac{12Ix_3l_1^2r^4(\dot{\alpha}_1-\dot{\alpha}_2)^4v_A^2}{16(v_A^2+\frac{r^2}{4}(\dot{\alpha}_1-\dot{\alpha}_2)^2)^4} + \tfrac{Ix_3l_1v_A}{v_A^2+\frac{r^2}{4}(\dot{\alpha}_1-\dot{\alpha}_2)^2} + \\
& -\tfrac{8Ix_3l_1r^2(\dot{\alpha}_1-\dot{\alpha}_2)^2v_A}{4(v_A^2+\frac{r^2}{4}(\dot{\alpha}_1-\dot{\alpha}_2)^2)^2} + \tfrac{8Ix_3l_1r^4(\dot{\alpha}_1-\dot{\alpha}_2)^4v_A}{4(v_A^2+\frac{r^2}{4}(\dot{\alpha}_1-\dot{\alpha}_2)^2)^3})r - \tfrac{1}{8}Ix_3v_Ar^3(\dot{\alpha}_1 - \dot{\alpha}_2)^2 \\
& (\ddot{\alpha}_1 - \ddot{\alpha}_2)(\tfrac{\frac{r^6}{64}(\dot{\alpha}_1-\dot{\alpha}_2)+(12l_1v_A-13v_A^2)\frac{r^4}{16}(\dot{\alpha}_1-\dot{\alpha}_2)^4}{(v_A^2+\frac{r^2}{4}(\dot{\alpha}_1-\dot{\alpha}_2)^2)^5} + \\
& -\tfrac{(30l_1v_A^3+5v_A^2)\frac{r^2}{2}(\dot{\alpha}_1-\dot{\alpha}_2)^2+6l_1v_A^5+9v_A^6}{(v_A^2+\frac{r^2}{4}(\dot{\alpha}_1-\dot{\alpha}_2)^2)^5}) + Iz_1\ddot{\alpha}_1 = \\
& M_1 - N_1f_1\mathrm{sgn}(\dot{\alpha}_1) - \tfrac{(\cos(\frac{r}{2l_1}(\alpha_1-\alpha_2))+\sin(\frac{r}{2l_1}(\alpha_1-\alpha_2)))rN_3f_3\mathrm{sgn}(\dot{\alpha}_3)}{2r_3}
\end{aligned}
$$

$$
\begin{aligned}
& r^2(2m_3l_1^2\ddot{\alpha}_1 + m_4l_1^2r\dot{\alpha}_2 + m_3l_5r\dot{\alpha}_2^2 - (2m_3l_5r + 2m_4l_2r)\dot{\alpha}_1\dot{\alpha}_2 + m_3l_5r\dot{\alpha}_1^2 \\
& +2m_4l_1^2\ddot{\alpha}_2 + 2m_4l_1^2\ddot{\alpha}_1 + 2m_3l_1^2\ddot{\alpha}_2 + 4m_2l_1^2\ddot{\alpha}_2 + m_4l_2r\dot{\alpha}_1^2)/8l_1^2 + \\
& -\tfrac{r}{2}(((m_1 - m_2)\cos(\tfrac{r(\alpha_1-\alpha_2)}{2l_1})l_1 + (m_4l_2 + m_3l_5)\sin(\tfrac{r(\alpha_1-\alpha_2)}{2l_1})) \\
& (\tfrac{1}{2}(\ddot{\alpha}_1 + \ddot{\alpha}_2)\cos(\tfrac{r(\alpha_1-\alpha_2)}{2l_1})r + \tfrac{(\alpha_2^2-\alpha_1^2)\sin(\frac{r(\alpha_1-\alpha_2)}{2l_1})r^2}{4l_1}) + \\
& +((m_1 - m_2)\sin(\tfrac{r(\alpha_1-\alpha_2)}{2l_1})l_1 - (m_4l_2 + m_3l_5)\cos(\tfrac{r(\alpha_1-\alpha_2)}{2l_1})) \\
& (\tfrac{1}{2}(\ddot{\alpha}_1 + \ddot{\alpha}_2)\sin(\tfrac{r(\alpha_1-\alpha_2)}{2l_1})r + \tfrac{(\alpha_1^2-\alpha_2^2)\cos(\frac{r(\alpha_1-\alpha_2)}{2l_1})r^2}{4l_1}) + \\
l\ & +\tfrac{1}{2l_1}(Ix_1 + m_2l_1^2 + Iz_4 + Ix_3 + m_4l_2^2 + Ix_2 + m_1l_1^2 + m_3l_5^2 + \tfrac{Iz_3l_1^2}{r_3^2} - \\
& \tfrac{6Ix_3l_1^2r^2(\dot{\alpha}_1-\dot{\alpha}_2)^2v_A^2}{4(v_A^2+\frac{r^2}{4}(\dot{\alpha}_1-\dot{\alpha}_2)^2)^3} + \tfrac{12Ix_3l_1^2r^4(\dot{\alpha}_1-\dot{\alpha}_2)^4v_A^2}{16(v_A^2+\frac{r^2}{4}(\dot{\alpha}_1-\dot{\alpha}_2)^2)^4} + \tfrac{Ix_3l_1v_A}{v_A^2+\frac{r^2}{4}(\dot{\alpha}_1-\dot{\alpha}_2)^2} + \\
& -\tfrac{8Ix_3l_1r^2(\dot{\alpha}_1-\dot{\alpha}_2)^2v_A}{4(v_A^2+\frac{r^2}{4}(\dot{\alpha}_1-\dot{\alpha}_2)^2)^2} + \tfrac{8Ix_3l_1r^4(\dot{\alpha}_1-\dot{\alpha}_2)^4v_A}{4(v_A^2+\frac{r^2}{4}(\dot{\alpha}_1-\dot{\alpha}_2)^2)^3})r - \\
& \tfrac{1}{8}Ix_3v_Ar^3(\dot{\alpha}_1 - \dot{\alpha}_2)^2(\ddot{\alpha}_1 - \ddot{\alpha}_2)(\tfrac{\frac{r^6}{64}(\dot{\alpha}_1-\dot{\alpha}_2)+(12l_1v_A-13v_A^2)\frac{r^4}{16}(\dot{\alpha}_1-\dot{\alpha}_2)^4}{(v_A^2+\frac{r^2}{4}(\dot{\alpha}_1-\dot{\alpha}_2)^2)^5} + \\
& -\tfrac{(30l_1v_A^3+5v_A^2)\frac{r^2}{2}(\dot{\alpha}_1-\dot{\alpha}_2)^2+6l_1v_A^5+9v_A^6}{(v_A^2+\frac{r^2}{4}(\dot{\alpha}_1-\dot{\alpha}_2)^2)^5}) + Iz_2\ddot{\alpha}_2 = \\
& M_2 - N_2f_2\mathrm{sgn}(\dot{\alpha}_2) - \tfrac{(\cos(\frac{r}{2l_1}(\alpha_1-\alpha_2))+\sin(\frac{r}{2l_1}(\alpha_1-\alpha_2)))rN_3f_3\mathrm{sgn}(\dot{\alpha}_3)}{2r_3}
\end{aligned}
\tag{5}
$$

All the parameters of the above equations were introduced in this publication, section 2.2.

To illustrate minirobots dynamics a suitable model was built using MATLAB / SIMULINK programme and the above solution of reverse dynamics problem was simulated. The moments which resulted from the simulation [4] will be used to select a proper drive; they will also indicate strengths and weaknesses of the construction. The moment characteristics were shown below:

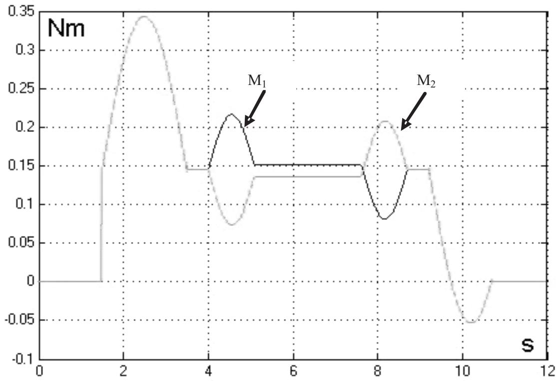


Figure 14 Wheel driver moments, without self-adjusting wheel (considered)

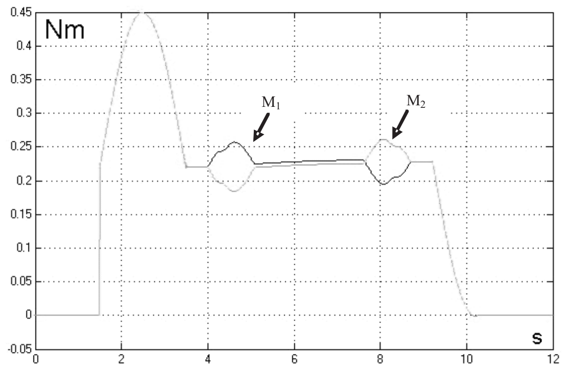


Figure 15 Wheel driver moments, with self-adjusting wheel (considered)

Simulations proved that self-adjusting Wheel Has Littre influence on *M.R.K* dynamics and steering

4. *M.R.K* construction

M.R.K construction is based on PLC controller by *GE Fanuc* [9,10] UAL 004, two 12V DC engines by MICRO MOTORS (maximum speed 18rpm, turning moment 140 mNm, capacity 20N),3 wheels and plastic framework. The sensors applied in the construction are: an infrared distance sensor by WENGLOR SENSORIC, a camera with WiFi vision and sound transmitter and receiver, ultrasound close-up sensor, 4 bumper sensors, 2 MEGATRON encoders of 100 *Pulse/Rev* resolution

4.1. *Master unit*

M.R.K. control is carried out through a *GE Fanuc* controller; a device of many programming and communication options. There is a range of digital inputs/outputs and two analog outputs and one input. The controller is equipped with two communication ports RS 232/485 [10,11].

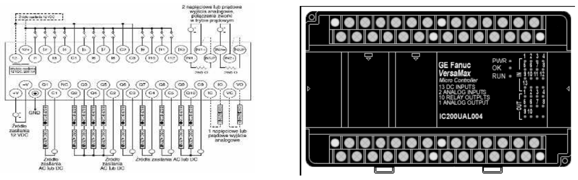


Figure 16 Microcontroller

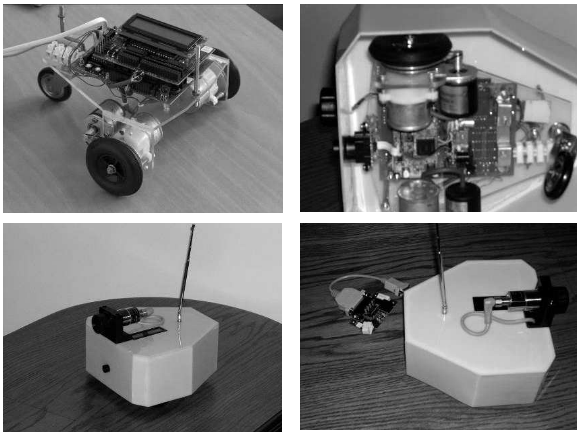


Figure 17 Mobile Minirobot – object of real

4.2. *Power supply system*

The power supply system consists of two dry batteries with a voltage of 6V and a capacity of 1.2 Ah. the batteries supply: microcontroller and infrared sensor. Other components are supplied directly from microcontroller *GE Fanuc*.

4.3. *Steering system*

The Wheels are driven by DC engines by MICROMOTORS (B138F type). The engines are supplied with 12V, current at max. torque 50 mA, maximum speed 18 rpm, maximum torque 140 mNm, maximum load 20N. the engines are steered by a PLC controller.

The sensors used in the MRM model enabled its orientation in space and observation of movement parameters such as angular speed of the driving wheels $\alpha_1 \quad \alpha_2$.

The angular speed was measured using MEGATRON encoder of MOZ/100/5/ BZ/K type. The sensors have 100 resolutions PPR, current consumption under 80mA, open collector output. The speed is recorded in the inside memory of the microcontroller.

Idler transmission transfers the drive onto the encoders, which results in better sensor signal resolution.

M.R.K is also equipped with an infrared distance sensor made by WENGLOR SENSORIC, this high quality sensor is able to measure the distance from 5 to 50 centimeters from an obstacle.

Figure 18 DC–motor BF138F

Figure 19 Opto–electronic incremental encoders

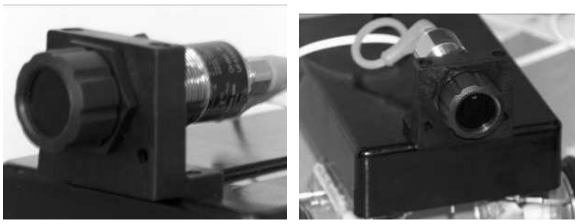


Figure 20 Install infrared sensor

The sensor above is used to measure the distance from the obstacle. When the safe distance limit is surpassed, the minirobot takes adequate decision to change the movement trajectory, which is possible due to implemented artificial intelligence.

As mentioned before, $M.R.K$ is also equipped with ultrasound distance sensors which protect the minirobot against a collision with an obstacle.

The mobile minirobot model is equipped with a device enabling remote vision and sound transmission. It works on a 1.3 GHz frequency, which allows signal transmissions for up to 300 meters in open space and 100 meters in closed area (building).

5. Visual-control panel

Visualization of the minirobot parameters is possibile thanks to the combination of programmes of SCADA type [7,10,11,12], Matlab/Simulink [9,13] and MsSQL data base.

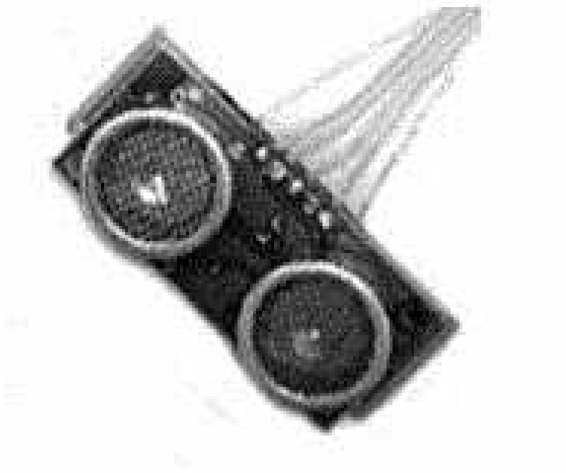


Figure 21 Supersonic sensor of distance

Figure 22 Remote vision and sound transmission

Currently, the market offers many systems of SCADA type; the most popular are: iFix, WIZCON, InTouch. In this project the following programmers were used for control: *InTouch* made by *Wonderware*, *Matlab/Simulink* made by *MathWorks* and *MsSQL* by *Microsoft*. The operation pattern of the system is shown below:

6. Verification of mobile robot control system

Mobile minirobot control is carried out with the use of *GE Fanuc* programmer and parameter-verification system. The driver carries out the programmer saved in its memory and transmits the most important information to the master unit.

Microcontroller PLC is programmed thanks to the application of the *Profice ME* package [10,11], which uses high level language of *LADER* type. Such programming

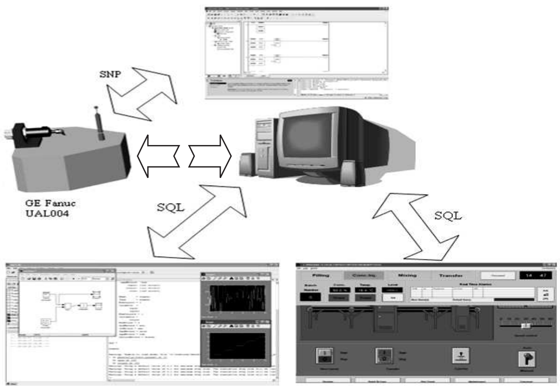


Figure 23 The system controlling *M.R.K*

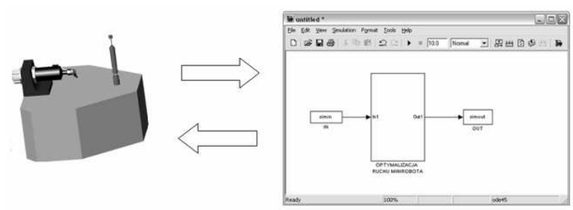


Figure 24 Scheme showing the data Exchange between PLC and *MATLAB*

creates a wide range of additional options: diagnostic and visual. The modification of such a programme is relatively easy and enables integration with other external units like visual packages.

Matlab package is implemented here as a supporting and steering system. The combination of this programme and the driver has revealed a number of useful but unused options for robot control. Among others, it is a change of some motion parameters while carrying out certain algorithms. In the case discussed here, it is achieved through *Matlab/Simulink* package which verifies and optimizes selected motion parameters and then transmits them to the programmer.

External communication used in steering, based on *WiFi* radiomodem net, and in the case of internal communication (SCADA system - Matlab), data base MsSQL is applied after DDE/SuitLink transmission.

SCADA system play a role of a control panel in mobile minirobot steering, which enables the *on-line* observation of the minirobots operation using a visual system as well as a verification of all motion parameters: driving moments, angular velocity and relocation for individual wheels velocity and minirobot framework relocations. Additionally the system shows the state of all *M.R.K.* installed sensors.

Visualization created in this project is based on *InTouch* programme by *Wonderware* Company. The programme allows a wide range of drawing and communication option owing to a great number of added communication protocols. The research shows that this environment is suitable for this kind of a system. Due to the integration of Matlab/Simulink, InTouch programmes, the signals from the installed sensors and the camera it was possible to achieve full control over the minirobots operation. The obtained results are presented below:

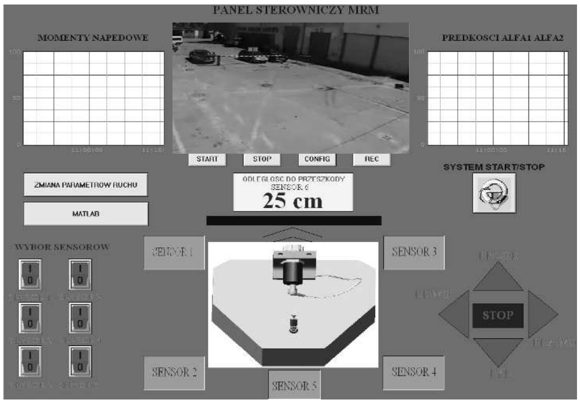


Figure 25 *M.R.K* steering system scheme executed In InTouch programmer

The above show the control panel operating not only individual sensors but also measurements of the most important motion parameters. There are two ways of steering the robot, through the algorithm saved in the driver memory and the steering keys (forward, backward, left, right, stop).

MATLAB button gives direct access to the program (Matlab/Simulink packge) carrying out the algorithm, using artificial intelligence – fuzzy logic algorithms [5,7]. Fuzzy logic algorithms are used here especially for interpreting and taking suitable actions for individual sensor signals.

7. Summary

This publications demonstrates the *M.R.K* wheel minirobot construction and the way of its designing. The criteria for engines selection were described as well as the method of fast prototyping with the Matlab and Intouch package use. Chapter 3 describes mobile robot kinematics and dynamics modeling along with respective simulations carried out in Matlab/Simulink programme. Kinematics modeling revealed that the self-adjusting wheel may have considerable influence on the system dynamics and steering, but to its limited impact on the system.

The results obtained during kinematics parameters simulation led to a decision to check the wheel influence which proved its impact to be limited and of little significance for the whole system dynamics. The wheel should be attached in such mode that the resistance during the drive is reduced to minimum.

The application of InTouch visual system and Matlab/Simulink package to the mobile minirobot steering allowed a range of new, unused options as well as enabled full control over the robot while carrying out a complex task.

The next stage of the project will be applying artificial intelligence methods, fuzzy logic and neural network.

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