Research the wheeled mobile robot kinematics parameters

Thesis · November 2018

DOI: 10.13140/RG.2.2.30391.98724

4 authors, including:

Dmitriy Mishchuk
Kyiv National University of Construction and Architecture (KNUCA)

Research the wheeled mobile robot kinematics parameters

Nataliia Semihanovska[1], Iryna Tereshchenko[1], Nataliia Filonenko[1], Dmytro Mishchuk[2]

[1]*Structural subdivision «Kyiv Industrial College» of the Kyiv National University of Construction and Architecture, 02000, 24A Novoukrainskaya street, Kyiv, Ukraine*

[2]*Kyiv National University of Construction and Architecture, 03037, 31 Povitroflotsky Avenue, Kyiv, Ukraine*

ABSTRACT

A theoretical research of a wheeled mobile robot is present, in which the dependences of the kinematics parameters on the geometric characteristics of the robot are determined. The purpose of this study is to analyze the methods of kinematic control for the further construction of control systems for mobile robots.

Keywords: kinematics, mobile robot, wheel, research

1. INTRODUCTION

Robotics of the construction industry is an inevitable process in modern realities [1]. Construction robots are able to replace heavy equipment, perform heavy manual work instead of a person, and automate complex technological processes, thereby increasing the productivity of construction work and minimizing industrial injuries.

Mobile automated robots are used for automated transportation of objects as well as for managing various logistic systems. The most developed and widespread wheel robotic mechanisms that are widely used in industrial automated transportation and storage systems and flexible automated production in the form of mobile, automatically controlled trucks (robot car) and can be equipped with various handling devices [2].

2. PURPOSE

With a sufficient amount of theoretical studies [2] - [5] in this direction, an analytical mathematical model of the motion of a wheeled robot has not been finally built. In this paper, it is proposed to investigate the kinematic characteristics of a mobile robotic platform and establish an analytical relationship between the parameters of a wheeled robot and the coordinates of its movement.

3. THE RESULT OF THE STUDY

The study examines a robot, which consists of a platform, two driving wheels - right and left, an ultrasonic distance sensor and infrared sensors. The diameter of the wheels is D and the width of the platform between the longitudinal centers of the drive wheels is B. The calculation scheme of the robotic platform is shown on Fig. 1. The robot is displaced by the rotation of two separate driven wheels separately, and then the linear velocity of the center of the platform and the angular velocity of its rotation will be:

$$\upsilon = \frac{\upsilon_R + \upsilon_L}{2} = \frac{D}{4}(\omega_R + \omega_L)\,; \qquad (1)$$

$$\frac{d\varphi}{dt} = \omega = \frac{\upsilon_R - \upsilon_L}{B} = \frac{D}{2B}(\omega_R - \omega_L)\,, \qquad (2)$$

where ω_R and ω_L are the angular velocities of the right and left driven wheels.

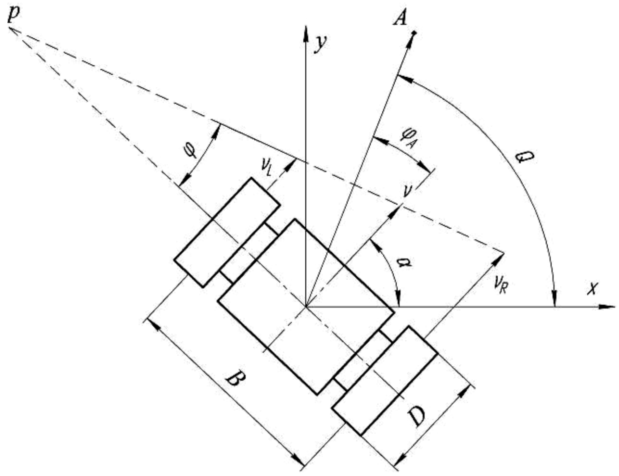

Figure 1. Scheme of a wheel robotic platform: B – platform width; D – diameter of the drive wheel; φ - the angle of rotation of the platform; υ, υ_R, υ_L – center speed of the platform, right and left wheel respectively

From equations (1) and (2), we can express the angular velocities of the steered wheels through the linear velocity of the platform and its angular speed of rotation in the plan:

$$\begin{cases} \omega_R = \dfrac{2\upsilon + \omega B}{D}; \\ \omega_L = \dfrac{2\upsilon - \omega B}{D}. \end{cases} \qquad (3)$$

The speed of rotation of the left and right drive motors, respectively, will be express by the following dependencies:

$$\begin{cases} n_{дв\_R} = \dfrac{\omega_R u_p}{2\pi}; \\ n_{дв\_L} = \dfrac{\omega_L u_p}{2\pi}, \end{cases} \qquad (4)$$

where u_p – gear ratio.

Turning radius work with uneven rotation of the left and right wheels is equal to:

$$R_L = \frac{\upsilon_L B}{\upsilon_R - \upsilon_L} = \frac{\omega_L B}{\omega_R - \omega_L}\,. \qquad (5)$$

To determine the movement of the robot along the x and y axes in the coordinate system relative to the center of work, consider the scheme of its movement in Fig.2, where Δpcd, Δpab, Δpkn – similar triangles. In the triangle Δpab, as an isosceles one $pa = pb = R_L$+B/2, and the angle of $\angle pab$ equals:

$$\beta = \frac{\pi}{2} - \frac{\varphi}{2}. \quad (6)$$

Then: $\gamma = \frac{\varphi}{2}$.

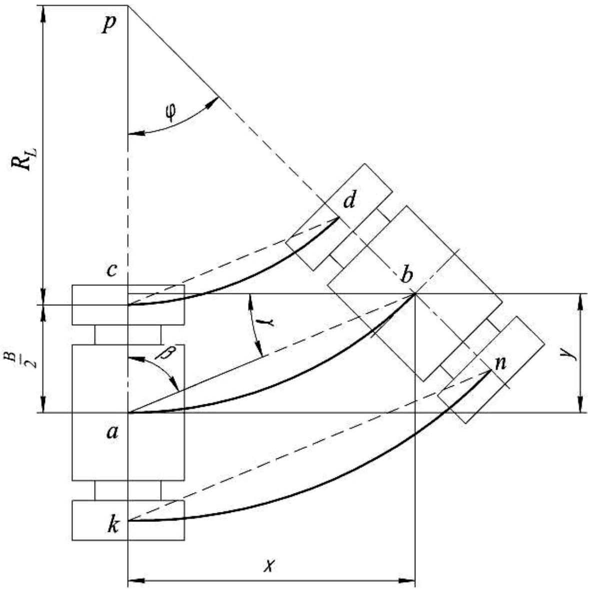

Figure 2. The scheme of movement when turning work

Since the length of the chord $ab = 2(R_L + B/2)\cdot\sin(\varphi/2)$, then the distance to which the robot will shift during movement will be determined by the following formulas:

$$x = (R_L + \frac{B}{2})\sin\varphi; \quad (7)$$

$$y = (R_L + \frac{B}{2})\sin^2(\frac{\varphi}{2}). \quad (8)$$

Using a similar approach as in [6], we determine the distance traveled by the robot:

$$S = \sqrt{x^2 + y^2}. \quad (9)$$

The required speed platform [6]:

$$\upsilon = \frac{dS}{dt} = \frac{x\frac{dx}{dt} + y\frac{dy}{dt}}{\sqrt{x^2 + y^2}}, \quad (10)$$

де $\frac{dx}{dt} = (R_L + \frac{B}{2})\cos\varphi \cdot \omega$; $\frac{dy}{dt} = \frac{1}{2}(R_L + \frac{B}{2})\sin\varphi \cdot \omega$.

The speed of the robot's work on coordinates can also be express through the angular velocities of its wheels:

$$\frac{dx}{dt} = \cos\varphi \frac{(\omega_R + \omega_L)D}{4}; \quad (11)$$

$$\frac{dy}{dt} = \sin\varphi \frac{(\omega_R + \omega_L)D}{4}. \quad (12)$$

4. CONCLUSION

In the presented study, the main kinematic dependencies of a mobile transport robot are considered, but they are not sufficient to plan the trajectory of its movement. To construct a robot control system, one can use methods such as: a vector field histogram [7], a close range diagram [8], a tangential avoidance [9], the application of a function gradient to areas of the configuration space [10]. In the future will is necessary to determine a dynamic picture of the behavior of the robot systems.

References

[1] Mischuk, D. (2013). The review and analysis of designs robots for construction works. Mining, construction road and melioration machines, Nr.82, P.28-37.

[2] Bloss, R. (2014). Robots have come to architecture to model, construct, fabricate and offer new approaches to create innovative designs, elements and structures. Industrial Robot: An International Journal, 41, P.403–407.

[3] Siegwart, R. and Nourbakhsh, Il.R. (2004). Introduction to Autonomous Mobile Robots, The MIT Pres Publ., London, England, P.321.

[4] Pelevin, L.E., Pochka, K.I., Garkavenko, A.M., Mishchuk D.A., Rusan, I.V. (2016). Sintez robototehnichnyh system v mashinobuduvanii, Interservis Publ., Kyiv, P.258.

[5] Ruggiero, A., Salvo, S., St. Laurent, Ch. (2016). Robotics in Construction: IQP Final Report. Worcester Polytechnic Institute, P.70.

[6] Mischuk, D. (2014). Kinematic analysis of manipulation systems of construction robots. Bulletin of the Kharkiv National Automobile and Highway University, Nr.65-66, P.90-96.

[7] Bolshakov, A.A., Stepanov, M.F., Stepanov, A.M., Uljanina, J.A. (2010). Planning of a trajectory of movement of the mobile robot. Bulletin of the Saratov State Technical University, P.176-180.

[8] Tretyakova, V.I., Musatenko, K.A. (2015). Simulation of the motion of an inertial transport robot with the choice of a quasioptimal trajectory in the presence of external interference and a priori insufficiency of information. The young scientist, Nr.10, 63-68.

[9] Matveeva, A.S. Hoyb, M.C. Savkinb, A.V. (2015). A globally converging algorithm for reactive robot navigation among moving and deforming obstacles. Automatica, Vol.54, P.292-304. (doi.org/10.1016/j.automatica.2015.02.012).

[10] Pykhtin, P.S., Kamaev, V.A., Kryzhanovsky, A.I., Niklyaev, I.Yu., Pykhtin, P.S. (2014). Planning the trajectory of a mobile robot using the gradient function of exploring areas of configuration space. Kibernetica i programirovanie, Nr.1, P.48-60. (doi.org/10.7256/2306-4196.2014.1.9828).