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Analysis of non-slipping conditions for Omni wheels based on investigations of the dynamics of a highly maneuverable mobile robot

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Abstract: The paper presents the investigations of the dynamics of Omni wheels considered as part of a mobile platform. The equations of motion are presented in the form of Lagrange equations of the second kind with undetermined multipliers. The investigation of the dynamics is based on the analysis of reaction forces, acting on wheels from the side of the support surface. The analysis of the dependences of reaction forces is carried out for different motion parameters: velocities, accelerations, and trajectory curvature.

Keywords: omnidirectional mobile robot, nonholonomic model, slipping, simulation.

1. Introduction

Mobile robots with omniwheels have a distinctive feature – the ability to implement omnidirectional motion. Control tasks for a mobile robot with omniwheels were previously considered in [1] – [4]. However, for mobile robots with omniwheels the control actions can be determined if the non-slipping conditions for wheels are satisfied. This work is devoted to the investigation of the dynamics of wheels for various motion parameters: velocities, accelerations, and trajectory curvature.

2. Mathematical model

Let's consider the robot's motion in a horizontal plane (see Fig. 1a). Details on the design, kinematic and dynamic models of the mobile platform with omniwheels can be found in [1, 2]. In other works [5, 6] the dynamics of mobile robots with omniwheels is considered only for limited sets of trajectory segments.

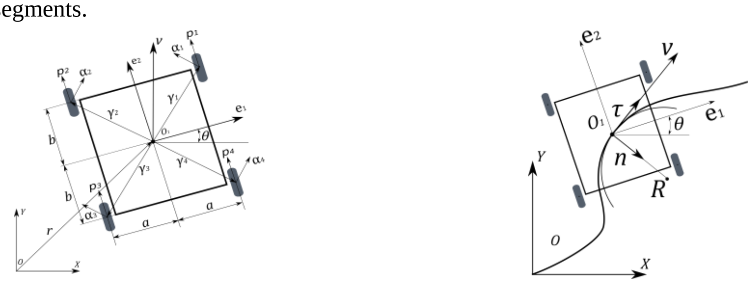

Fig. 1. a) The scheme of a mobile platform with omniwheels and b) curvilinear trajectory of motion

To determine the possibility of implementing motion along a trajectory with different motion parameters consider the dynamics of an individual wheel as part of a mobile platform. The equations of motion of an individual wheel consider in the form of Lagrange equations of the second kind with undetermined multipliers relative to the coordinate system associated with the mobile robot (see Fig. 1a):

$$m_i \dot{\mathbf{v}}_i + m_i \omega \mathbf{J} \mathbf{v}_i = \frac{\lambda_i}{(\boldsymbol{\alpha}_i, \boldsymbol{p}_i) h_i} \boldsymbol{\alpha}_i + \boldsymbol{\mu}_i, \tag{1}$$

$$I \dot{\omega} = -(\boldsymbol{\mu}_i, \mathbf{J} \boldsymbol{\gamma}_i). \tag{2}$$

Solving the system (1)-(2) relative to undetermined multipliers λ_i, taking into account the radius of curvature of the trajectory, we obtain:

$$F_i = \frac{(\boldsymbol{\alpha}_i, p_i)}{(\boldsymbol{\alpha}_i, \mathbf{J}\boldsymbol{\gamma}_i)} \left((I + m_i \boldsymbol{\gamma}_i^{\ 2}) \ddot{\theta} + m_i (\mathbf{Q}\boldsymbol{\tau}, \mathbf{J}\boldsymbol{\gamma}_i) \ddot{s} + m_i (\mathbf{Q}\boldsymbol{n}, \mathbf{J}\boldsymbol{\gamma}_i) \frac{\dot{s}^2}{R} + 2 m_i (\mathbf{Q}\boldsymbol{\tau}, \boldsymbol{\gamma}_i) \dot{\theta} \dot{s} \right), \tag{3}$$

where $F_i = (\lambda_i / h_i)$ - the module of the reaction force, acting on the *i*th wheel from the side of the support surface, $\dot{s}$ - the module of linear velocity, $\dot{\theta}$ - angular velocity of the mobile robot.

The resulting expression (3) describes a combination of several cases of mobile robot's motion. These cases require separate consideration:

1. Non-stationary motion along a straight line with a constant orientation.
2. Non-stationary rotation.
3. Stationary motion along a straight line with constant linear and angular velocities.
4. Stationary motion along a curvilinear trajectory with a constant orientation.

3. Conclusion

In this work, the influence of velocities, accelerations and trajectory curvature was determined based on investigations of the dynamics and numerical modeling.

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