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Modelling of motion and experimental studies of a four-wheeled mobile robot considering slip occurrence

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Abstract: The results of the simulation and experimental investigations of motion of the four-wheeled mobile platform are presented in the paper. The simulation results have been based on the description of the dynamics of wheeled mobile platforms. The description of the platform dynamics is presented in the paper. The initial problem of the platform motion has been solved using the Runge-Kutta integration method of fourth order. The relationship between active and passive forces accompanying the platform motion have been taken into account in the dynamic model of the motion of the system. The dynamics model has been verified by experimental tests using the LEO Rover robot. On the basis of the dynamics model, simulations of motion have been carried out in order to obtain the system response to the given forcings. The proposed model of motion dynamics has been verified by examining the real motion of the robot. Experimental studies of the robot's test runs along a rectilinear and curvilinear trajectory have been presented. The obtained motion parameters in the form of trajectory, velocities and accelerations have been compared with the results of experimental tests, and the results of this comparison have been included in the paper.

Keywords: motion dynamics; wheel slippage; wheeled mobile platforms, friction.

1. Introduction

The model of the dynamics of motion of a four-wheeled mobile platform has been presented in the work. Mobile platforms find a number of applications to support human work or to replace it in places inaccessible to him. The design of the platform results from the intended purpose of its work. Hence, there are many technical solutions that, for example, perform the tasks of inspecting the inner part of the pipes [1], help in the movement of people, where in the work [2] a special trolley equipped with a collision-free system for tracking pedestrians has been described. Moreover, robot solutions are being developed to facilitate visiting museums and libraries. More and more often, mobile platforms are equipped with a set of independent steering wheels, which makes it possible to drive them in multiple directions and to implement complex translational and rotational trajectories. Therefore, it is necessary to study the movement of wheeled mobile robots, which in essence focus on the study of kinematics and dynamics of motion. The problem of simple kinematics has been described, among others in [3]. Investigation of the kinematics and inverse dynamics of a three-wheeled mobile robot with two steerable wheels and one self-adjusting one, using virtual work methods have been included in [4], however, the impact of slippage has been neglected. In modelling the kinematics and dynamics of motion of wheeled mobile platforms, the plane motion model is most often adopted. This is due to

the purpose and nature of the work of mobile platforms. Therefore, considerations about the relationship between a drive wheel and the road surface are very important. In modelling the kinematics and dynamics of motion, the problem should not be simplified to the assumption of pure wheel rolling, as this may indicate that the longitudinal and/or transverse slip in the wheel-ground contact does not occur, i.e. it is equal to zero.
The aim of this work was to propose a model of the dynamics of movement, with the use of which it will be possible to map the trajectory of the movement of a four-wheeled mobile platform not only taking into account the influence of friction forces, but also under the influence of exceeding the value of developed friction, which in turn will lead to skid of the drive wheels [5]. The results of such an analysis have been partially presented in [6]. Based on the results of the motion simulation and experimental tests, the results of test runs along a straight-line and curvilinear trajectories have been presented.

2. Results and Discussion

On the basis of the proposed description of the dynamics of motion of the wheeled mobile platform, the simulation tests of the movement of such an object with the use of various configurations of inputs implemented through an appropriately controlled wheel drive and taking into account the conditions of cooperation between the wheels and the ground have been carried out through appropriate models of such cooperation. The adopted model of the mobile platform has been built so that the description of the movement reflects the kinematic properties of the platform, as well as the control possibilities occurring during its operation. The verification of the robot's motion dynamics model was based on demonstrating compliance in the nature and values of the waveforms of the motion parameters obtained by experimental and analytical methods. The obtained results confirm the adopted assumptions and show compliance in both character and values.

3. Concluding Remarks

A computational model has been proposed, including an algorithm for solving the formulated problem of the initial movement of a four-wheeled mobile platform. On the basis of the developed calculation programs, simulation tests of the four-wheeled platform have been carried out, as a result of which the waveforms of the platform motion parameters have been obtained in relation to selected configurations of construction parameters and wheel drive configurations, including their slippage. On the basis of the proposed model of the dynamics of motion, it is possible to analyse various cases of motion, including the slip of road wheels. It is also possible to study the forces and reactions occurring during the movement.

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