Proceedings of the 29th Polish-Slovak Scientific Conference on Machine Modelling and Simulations 2024, Poland

Validation of the Dynamics Model of a Four-Wheeled Mobile Platform

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Motion modeling in physics involves determining the physical parameters of motion related to the change in the position of a point or rigid body over time described in the reference system. On the basis of the theoretical model of dynamics of motion presented in the authors' previous works, in this paper the results of numerical and experimental studies of the motion of a four-wheeled mobile platform are presented. The tests were carried out on the basis of plane motion, taking into account the occurrence of wheel slippage. Numerical tests were performed using an original computational algorithm that was used to obtain motion parameter data. Selected cases are described in the work and compared with experimental tests showing the physical parameters of the actual motion of the robot. The experimental research included test runs during which slippage was observed in the form of a deviation of the trajectory from the straight line of motion. Both the nature of the results in graphical form and the values of selected test runs with the corresponding motion simulations have been verified, and the results are included in the work. The conclusions are presented in the last chapter of the work.

topics: motion parameters, dynamics of motion, mobile platforms

1. Introduction

Complex analysis of the motion of wheeled mobile platforms includes observing the behavior of platforms and robots, modeling motion or generating trajectories of planned paths, as well as verification of the obtained motion parameters, environmental parameters, and circumstances in which the motion occurs with validation of the motion model. Hence, the validation of the obtained results of the motion parameters of a four-wheeled mobile platform based on test runs of experimental research was carried out in this work. Validation of the model includes examining the accuracy of the possibility of using the motion dynamics model presented in [1, 2] in relation to the real motion of the robot, taking into account the occurrence of slippage of the drive wheels. The results of experimental tests on straight and curvilinear trajectories were included in the work [2, 3], on the basis of which the possibility of slippage occurring during movement was verified. The results of this work were partly presented in [4]. This work extended the scope and included the results of six test runs. In [5], two simulation models were described in order to propose a useful and simple description for implementation in a simulator that will work in real time. Trajectory tracking control is a task described by [6]. The author presented the problem of integrating kinematic and dynamic trajectory tracking control for non-holonomic wheeled mobile robots. A proposal to track the desired robot trajectories with a time-varying forward direction was presented in [7]. In [8], research on the control of a complex mobile robot with system trajectory tracking was included. Work [9] presents an overview of the latest research trends in the field of research on skid-steer wheeled mobile robots (SSWMR). The authors pointed to gaps in research on mobile wheeled robots in the area of the development of autonomous unmanned ground vehicles. Work [10] presents a new solution of using omnidirectional wheels combining the capabilities of commonly used wheels and Mecanum wheels.

The contact of the wheel with the ground is one of the most important aspects of analyzing the motion of wheeled mobile platforms. Work [11] describes the results of research on the drive transmission system of a wheeled mobile platform using the finite element method. Work [12] presents the results of simulation tests taking into account the motion parameters and the wheel sink and slip parameters. The authors of work [13] proposed a solution to the problem of controlling a tractor with a semi-trailer as a model of a wheeled vehicle. The work presents a proposal for a control algorithm taking into account the slip compensation procedure. In [14], a proposal was presented to use uncertainties related to slip in order to minimize the drive torque in both the wheel drives and the manipulator, while achieving the required trajectory tracking accuracy. Modeling of motion and related tasks require in-depth knowledge of kinematics and dynamics of motion. Hence, attempts are made to formulate the problem and propose an algorithm based on which it will be possible to map real motion combined with the computational efficiency of the algorithm.

2. Experimental research and sample results

In order to validate the developed model of dynamics of motion [1, 2], a series of tests of the four-wheeled mobile robot LEO Rover [14] were carried out. It was planned to carry out tests along a straight-line trajectory with all-wheel drive. The aim of the research was primarily to demonstrate the possibility of wheel slippage. LEO Rover was equipped with four electric motors with planetary gears mounted directly on each wheel, constituting the robot's drive units. The robot is controlled using the TurtleApp application. The dimensions of the robot in the working plane are as follows: length equal to 414 mm and width equal to 438 mm. The weight of the robot without the manipulator is 61 N. Radius of the drive wheel is 0.064 m.

The results presented in this paper include six runs along a straight-line trajectory. Each run was carried out in the same conditions, inside the laboratory on the same surface. The independent input values included the values of wheel rotation angle excitations over time, set in the form of pulses separately for each drive, i.e., separately for each wheel of the platform. The constant values taken into account in the model are the mass and geometry of the platform, as well as the friction coefficient, also tested experimentally. Each ride was recorded on camera and was analyzed in the Tracker video analysis and modeling tool. The collected output data constituted a set of real parameters of the robot's motion, containing the values of coordinates in the adopted reference system, linear velocities and accelerations, and displacements.

The scope of the research included three stages of work. The first stage involved recording the robot's motion parameters based on the recording of forcing a given configuration of wheel drive impulses. The next stage was to record the real motion and, on this basis, obtain the values of the motion parameters of the robot's real motion. The third stage included comparing the results of experimental studies with simulation studies based on the dynamics model described in, among others, [1, 2]. In these studies, 6 test runs were carried out, lasting from 9 to 11 s.

First, an analysis of distances was carried out based on two sets of parameters, i.e., those recorded from forced motion and those recorded from real motion.

The values in the first phases of motion differ from each other in a way that indicates the possibility of slippage. The values of velocity in the runs were compared with the real motion of the robot. In both cases, the differences indicated the possibility of slippage occurrence in test runs. The examples were discussed in [2, 3].

3. Validation of the model

Simulations were performed in the MATLAB environment based on the author's computational algorithm. The results of comparing the values and nature of the velocity, based on the real motion by observing a selected point of the robot's body, and for the center of mass of the platform in the MATLAB simulation results are shown in Figs. 1–6.

Based on the velocity results (Figs. 1–6) and displacements (not included in the paper), it can be stated that the vlidation studies of the robot motion are consistent. This results from the nature and values of the obtained velocity–time dependencies in the real motion and in the motion simulation

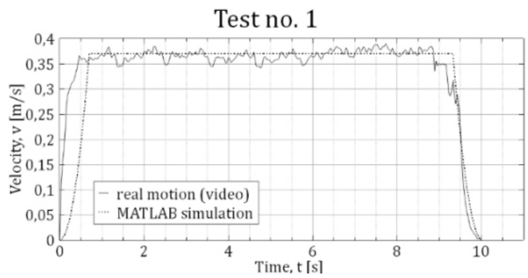

Fig. 1. Velocity values in the first test run compared to results of simulation of motion.

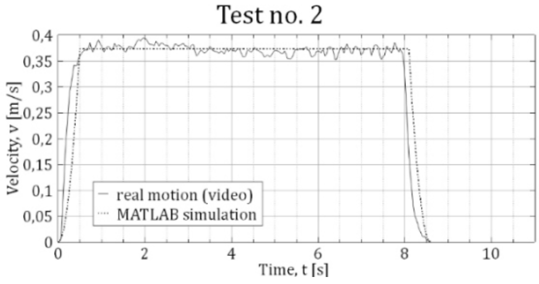

Fig. 2. Velocity values in the second test run compared to results of simulation of motion.

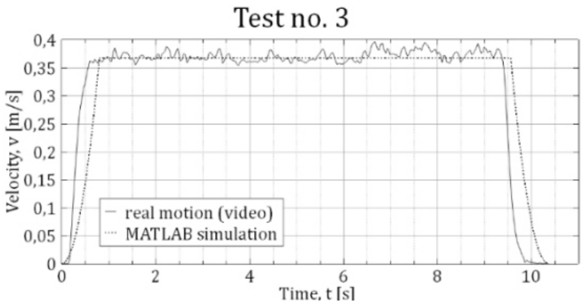

Fig. 4. Velocity values in the forth test run compared to results of simulation of motion.

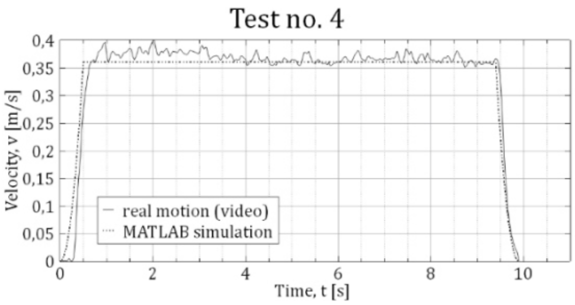

Fig. 5. Velocity values in the fifth test run compared to results of simulation of motion.

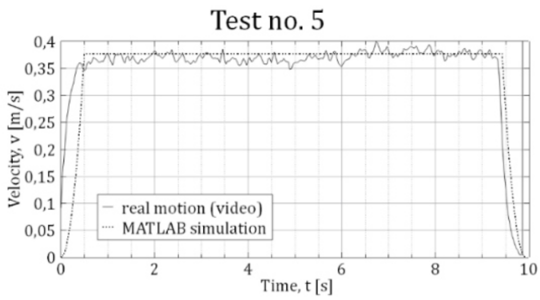

Fig. 6. Velocity values in the sixth test run compared to results of simulation of motion.

results based on the computational algorithm. The algorithm gives good convergence in simulation according to the experimental results.

4. Conclusions

The paper presents the results of driving a four-wheeled mobile platform along a straight trajectory. On the basis of the performed experimental research, differences were indicated in motion parameters. It was presented that wheel slippage during the robot's motion is possible. The results, both in quantitative and qualitative forms, were compared and confirmed. As a result of comparing the platform's motion velocity values obtained by computer simulation and experiment, a very good convergence between the compared motion parameters was demonstrated in the examined cases.

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