MATHEMATHICAL MODEL OF MOBILE ROBOT FOR PURPOSE OF PATH TRACKING OF THE ROBOT

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Abstract: This article is about designing and constructing a four-wheel chassis, which will possess better negotiability of diverse terrain. One of the main features of mechatronic approach to designing advanced products is complex understanding of the technical object and its computer modeling. Simulation model of a mobile robot equipped with the sectional undercarriage it is useful to apply methods of kinematic analysis and synthesis of bonded mechanical systems.

Keywords: mobile robots, simulation

1 Introduction

The kinematic description of mechanical system issue from an abstraction – simplification of reality. In simulation model we integrate mechanical, electrical and control subsystem and thus acquire information about their mutual interactions. Analyzed is a used concept of chassis motion control of mechatronic systems on the principle of differential wheel control for the task of active tracking of planned chassis path. It is possible to verify a large spectrum of applications, which can be typical for operation of the simulated subject.

2 The differential mobile robot

Differentially controlled mobile robots usually have three or four wheels. Driving wheels are fixed on both sides of robot and one or two wheels are supportive while being positioned in front or in rear. Robot can move forward or backward and is able to change head angle through speed control of driving wheels station.

2.1 Mathematical model of mobile robot

Computer-aided simulation of kinematics of mechanisms is an important integrated part of the modern approach to the design of technical subjects. Deformations of individual parts of the mechanisms can be neglected in a great number of practical tasks and that is why it is possible to apply the so-called system of rigid bodies with mutual interrelations.
Many principles of kinematics and dynamics of the three-dimensional mechanisms are very complicated to be understood without a necessary theory.

This mathematical model describes positions and velocities of the individual wheels. However, if the complex movements are disintegrated into the individual sequences of simple, basic steps, so the solution process can be simplified efficiently. Such disintegration is a standard part of all tasks concerning movement of bodies, practically. The so-called method of matrix kinematics is a very efficient and general method for solution of body movements and for all branch of kinematics, actually [1].

Application of the coordinate system instead of the body for definition of the positions and orientations is a more accurately method. The coordinate system can be connected directly with the body or not. The homogenous coordinates are applied for a simplification of operations with bodies in the three-dimensional space [2, 3].

For the mathematical description of a serial kinematic chain is best to use Denavit-Hartenberg principle of deployment of joint chain to the coordinate system [4].

The kinematic model of undercarriage takes into consideration the real dimension of the robot.

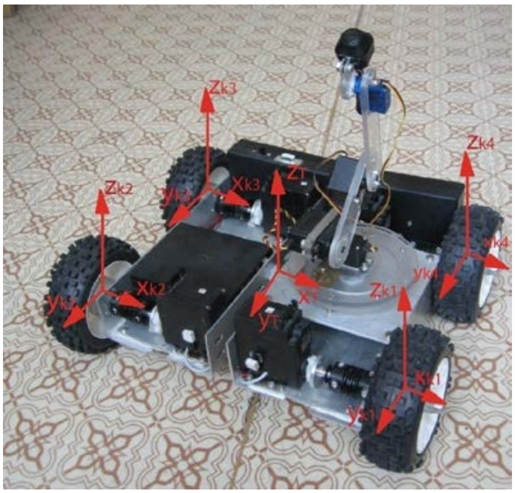

Fig. 1 Local coordinate systems

Chassis frame is composed of two pieces connected by a passive joint. Robot chassis has a four-wheel drive that does not lose traction even on diverse terrain surface thanks to the passive joint It enables both parts of frame to randomly tilt depending on terrain difficulty.
Hence it is achieved that every wheel in any moment keeps contact with terrain surface [2].

Transformation corresponding to shift in axes x,y,z, or transformation corresponding to rotation around defined axes represents coordinate qi [5,6].

Resulting transformation matrix of wheel 1 position and rotation to geometric center of gravity of chassis:

$$T_{k1}=\begin{bmatrix} \cos(q1) & -\cos\left(\frac{q4}{2}\right)\sin(q1) & \sin\left(\frac{q4}{2}\right)\sin(q1) & q2\cos(q1)-95\cos\left(\frac{q4}{2}\right)\sin(q1)-175\cos(q1)-q3\sin(q1) \\ \sin(q1) & \cos\left(\frac{q4}{2}\right)\cos(q1) & -\sin\left(\frac{q4}{2}\right)\cos(q1) & 95\cos\left(\frac{q4}{2}\right)\cos(q1)-175\sin(q1)+q3\cos(q1)+q2\sin(q1) \\ 0 & \sin\left(\frac{q4}{2}\right) & \cos\left(\frac{q4}{2}\right) & 95\sin\left(\frac{q4}{2}\right) \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Based on constructed transformation matrices it is possible to construct simulation models for defining center of gravity geometric position of chassis and wheels in Matlab/Simulink environment.

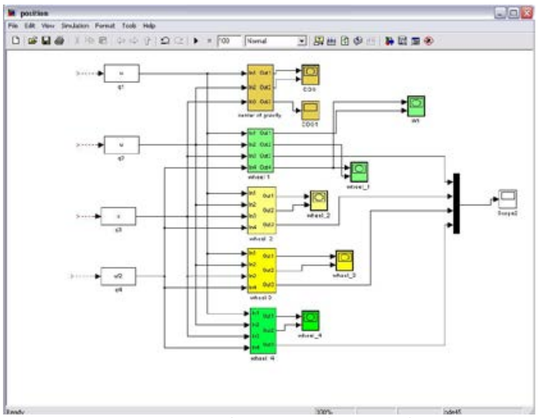

Fig. 2 Simulation model of position of center of gravity and wheels

Simulation model of position of geometric center of gravity of chassis and individual wheels comprises of several subsystems that have common input. Every subsystem represents position of wheel, or position of center of gravity to beginning O (Instantaneous Center of Rotation).

2.2 Control concept of chassis

There are particular restrictions for chassis motion which result from chassis parameters (wheels diameter, wheel base and geometry of wheels layout). Chassis motion should be stable and fluent to avoid slipping between wheels and terrain and to avoid mechanical shock resulting from rapid changes in chassis motion. However during chassis motion unavoidable trajectory deviations between current position and requested trajectory do occur because of path tracking control imperfection using wheels velocity and fault variables from environment (terrain roughness, friction forces changes between wheels and terrain and so forth) [7,8,9].

Trajectory deviations should be corrected online using requested linear and rotational chassis motion velocities by path tracking control .

In work [7] layout of kinematic control is designed, comprising of three levels of links (dynamic, kinematic and planning). This approach is similar to those, which are applied in robotic manipulators.

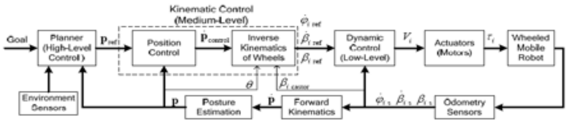

Fig. 3 Control scheme of the wheeled mobile robot [7]

3 Conclusion

Hence it is possible to use the model for calculating estimated or requested trajectory of chassis center of gravity and wheels. At the same time it is possible to examine model behavior in any given combination of chassis dimensions and relating to this there is an option of chassis geometry optimization in terms of obstacles negotiability on diverse terrain.

The created simulation model can be applied for calculation of assumed or intended path of the undercarriage centre of gravity and path of wheels.

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