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Parameters for Mobile Robot Kinematic Model Development Determination

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Abstract:

The problem of creating a mobile robot kinematic model is due to its necessity for controlling the robot. In this case, understanding the design features of the robot, as well as its movers, is of great importance. The primary task is to select the necessary parameters to create a kinematic model. The article discusses the design of the robot being developed. And a choice of parameters is proposed for creating a kinematic model of this mobile robot.

Key words: Mobile robot, Kinematic model, Kinematic characteristics, Navigation, Path development

Introduction

Mobile robots are becoming increasingly widespread in the modern world. They are used in many areas of human life. By purpose, we can distinguish next types of robots: transport robot, household robot, combat robot, zoomorphic robot, medical robot, pharmacy robot, microrobot, nanorobot, personal robot, social robot etc. [1]-[10].

To move around open areas, a wheeled or tracked propulsion device is most often used. Walking systems are used less frequently. For uneven surfaces, hybrid structures are created that combine wheeled or tracked travel with complex kinematics of wheel movement.

Indoors, at industrial facilities, robots move along monorails, along floor tracks, etc. To move along inclined or vertical planes, through pipes, systems similar to “walking” structures, but with vacuum suction cups, are used. Robots designed to inspect high-voltage power lines have a wheeled chassis in their upper part that moves along the wires. Robots are also known that use the principles of movement of living organisms - that is, zoomorphic robots and insectomorphic ones.

It should be noted that when creating any mobile robot, it is not enough to simply assemble the device. It is also necessary to develop the principles of its movement. Taking these principles into account, the next step is to develop a system, as well as a control program for this mobile robot [11]-[17].

Moreover, such a program must take into account the design features of the robot itself, as well as the type of room/open area where it will be used.

Thus, after determining the components of the designed device, it is necessary to develop its kinematic model for the further creation of a control system for this robot. For a kinematic model, it is first necessary to determine the main variables/parameters. This article will discuss the definition of these variables/parameters.

Related works

To create a control system for a mobile robot, many researchers first create a kinematic model of the robot being developed. Let's look at several recent of these works.

In article [18] authors present a new variable curvature kinematic modeling approach for soft continuum robots by taking the external forces into consideration. They achieve both accurate motion simulation and feed forward control of the robot.

The paper [19] explain the application of kinematic modeling of four wheel omni directional robots as track tracking controllers and microcontroller based movement control.

In [20] scientists consider the kinematics of the robot in active and passive modes composed of position and posture in order to develop a mathematical model for an effective design and control of the locomotion system.

Lafmejani, A. S. and co-authors [21] describe the kinematics modeling and control of hyper-redundant robots inspired by the octopus arm. They propose their solution for the inverse kinematics problem.

Paper [22] present a framework for estimating the kinematic model and configuration of previously unseen articulated objects, conditioned upon object type, from as little as a single observation.

Researchers in [23] propose their kinematic model with velocity compensation of the combined mobile system is created, aimed to provide a theoretical kinematic basis for accurate motion control.

In [24] a forward kinematic model of a wire-driven surgical robot arm is presented with an articulated joint structure and path generation algorithms with solutions of inverse kinematics.

Rabiee, S., & Biswas, J. propose a new kinematic model capable of slip prediction for skid-steer wheeled mobile robots [25].

The paper [26] by Toquica, J. S., & et al. proposes two solutions for the inverse kinematic problem of an industrial parallel robot: a closed analytical form and a Deep Learning approximation model based on three different networks.

Authors of the paper [27] establish the kinematics of cable-driven parallel robots considering pulley mechanisms and further develop the error model as well as the kinematic calibration method for cable-driven parallel robots.

In [28] researchers propose a method to learn the kinematic model of a redundant surgical robot and control it to perform surgical tasks both autonomously and in teleoperation.

Authors in [29] note, that kinematic models provided by robot manufacturers are valid only under ideal conditions and it is necessary to account for the manufacturing errors, particularly the joint offsets introduced during the assembling stages, which is identified as the underlying problem for position inaccuracy in more than 90% of the situations. They minimize the kinematic mismatch between the ideal and the factory-calibrated robot models for a Kinova Gen3 ultra-lightweight robot by compensating for the joint zero position error and the possible variations in the link lengths.

So, we see that many developers are building kinematic models. It should also be noted that the problem of solving kinematic problems, both direct and inverse, is the subject of research by many scientists.

Mobile robot kinematic model parameters determination

We need to understand that to build a kinematic model, you first need to determine at least the main characteristics of the designed mobile robot. We must also take into account that the more characteristics we take into account, the more accurate the kinematic model will be.

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However, an excessive number of such characteristics can lead to unnecessary, that is, excessive complication of the kinematic model. This number of characteristics may have virtually no effect on the control accuracy of a mobile robot.

Thus, when choosing characteristics for compiling a kinematic model of a robot, it is necessary to analyze their feasibility and the degree of influence on the accuracy of movement.

Within these studies framework, let us assume that the mobile robot moves along a known and bounded two-dimensional plane, which is discretized in the form of a grid. Each grid point corresponds to a small region of real space. If the space in this field is completely traversable, its state is considered free, otherwise it is considered occupied. The design of the wheeled mobile robot is standard and consists of two drive wheels on the left and right sides, the rationale for choosing this design is its availability and wide distribution, which will simplify the modeling process in the future. The general view of the selected design of the mobile robot is shown in Figure 1.

Figure 1: Mini Round Chassis 2WD DIY Smart Car

Let us represent the selected mobile robot in the XY coordinate plane and spread the base points for developing a kinematic model. Figure 2 presents a kinematic model of a 2WD mobile robot.

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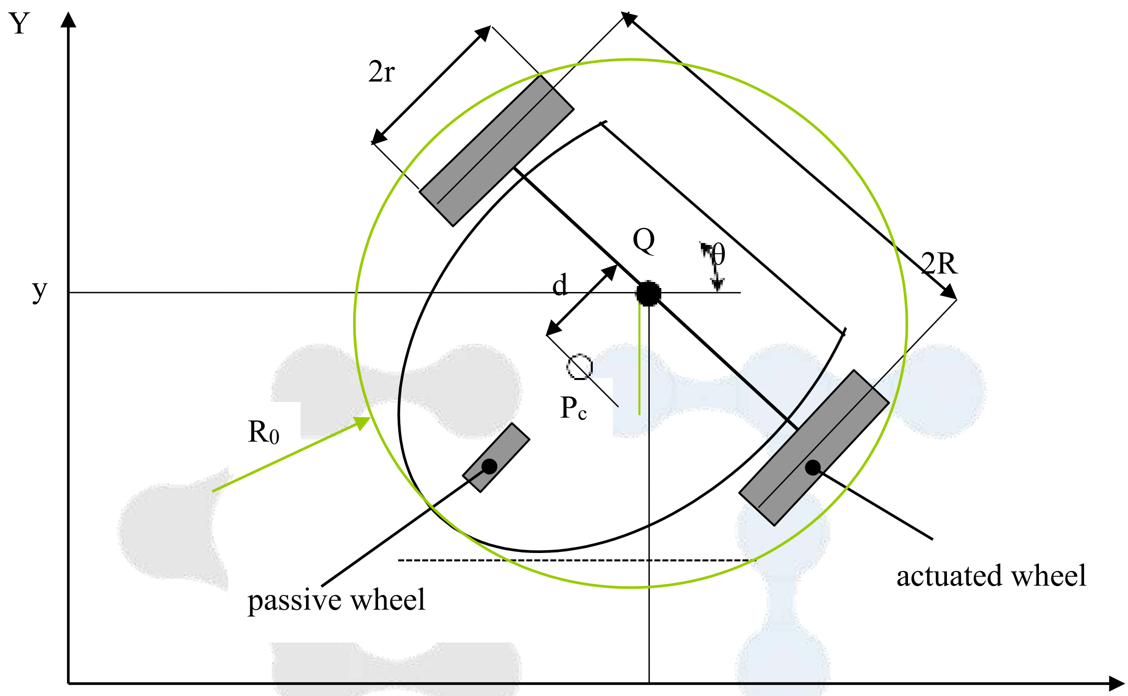

Figure 2: 2WD Mobile Robot Kinematic Model

Let us denote by P_c the center of mass of the mobile robot, which is an important part of robot design and control. The center of mass is the point where the entire mass of the robot can be considered concentrated;

Q is the midpoint of two actuated wheels, accounting for the midpoint of the two wheels is an important aspect when creating a kinematic model of a mobile robot to ensure its stable and controllable movement, as well as to develop efficient control and navigation algorithms;

d is the distance between P_c and Q, which is affected by the change in wheel speeds affects the movement of the robot center of mass. This is important for the development of motion control algorithms that allow the robot to move in the desired direction and perform the given maneuvers;

R is half the width of the wheel driven from left to right. Considering the half-width of the left-to-right (or right-to-left) driven wheel in the kinematic model of the mobile robot is an important aspect in this model development. This is done to take into account the characteristics of a robot with a differential drive or other systems where each wheel can be controlled independently;

r is the radius of the wheel. Taking into account the wheel radius in the kinematic model of a mobile robot is an important aspect, it provides an opportunity to account for the dimensions and features of the robot's wheels, which significantly affect its movement and maneuverability;

R_o is the radius of the smallest circle with center Q covering the entire robot. This radius, also known as the turning radius or maneuvering radius, determines how close the mobile robot can approach an obstacle or turn in a confined space.

We will also define three variables related to the coordinates of the robot:

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θ – the heading angle of the mobile robot, since the heading angle is the direction in which the robot is moving relative to its initial orientation. This angle is a key variable when describing the motion and controlling the robot

x та y – coordinates Q, necessary for an accurate description of the position and movement of the robot in space. These variables are used in the kinematic model of the robot and for solving navigation and control problems.

Within the framework of these studies, we will set such conditions that the wheels do not slip.

In the future, it is proposed to develop a kinematic model of the robot movement, which will take into account the following features when constructing the route of movement of the mobile robot:

- movement accuracy, it will be possible to more accurately predict the movement of the robot in response to certain movement commands or control signals. This will allow for more accurate consideration of the physical limitations of the robot, such as dynamic limits on acceleration and maximum speeds. When planning the path of the robot, these constraints can be taken into account to ensure safe and stable movement;

- the dynamic model will allow you to take into account friction and resistance forces that can affect the movement of the robot. This is especially important when planning a path on an uneven surface or in drag conditions such as sand or mud. Taking these factors into account makes it possible to more realistically design the path and prevent possible problems related to friction;

- collision avoidance: the proposed model allows predicting how the robot will move near obstacles. This allows the robot to avoid collisions with surrounding objects, taking into account both the robot's geometric parameters and its dynamic characteristics. Path planning based on this information allows the work to avoid dangerous situations;

- optimization of energy consumption by determining the dynamic characteristics of the robot, it is possible to optimize its movement from the point of view of energy consumption. This is important for battery-powered mobile robots because optimized motion can extend battery life.

Thus, the development of a full dynamic model will allow more accurate and efficient development of route construction algorithms taking into account its physical capabilities and limitations.

Conclusion

In the modern world, the use of robots is becoming more and more global. New devices are constantly being developed and invented, as well as efforts to develop them.

However, it is not enough to just develop the design itself. The robot must be controlled. Accordingly, the task of controlling the robot becomes mandatory, which also includes controlling its movement.

To solve these problems, control systems are developed and control programs are created.

The created program must ensure accurate movement of the mobile robot. To solve this problem, it is first necessary to create a kinematic model of the control device. Such a model must take into account all the necessary parameters and characteristics. However, the principle of expediency should be adhered to. That is, the characteristics taken into account in the kinematic model must be necessary and sufficient to control the movement of a mobile robot. But they should

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not be redundant. That is, you need to take into account only those that affect the movement of the robot.

This paper presents the selection of parameters for the subsequent creation of a kinematic model. In the future, it is planned to develop a kinematic model, as well as a control system based on it.

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