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DESIGN OF A FUNCTIONAL MODEL OF A THREE-WHEELED MOBILE ROBOT

Mobile wheeled robots are one of the most widespread group of service robots today. The simplicity of their design and their ability to better negotiate difficult terrain places them at the forefront. In practice, it is possible to find a variety of mobile wheeled robots, which differ from each other in the number and arrangement of wheels, the variety of structural design, or the suspension of the wheels and their suspension.

Current statistics confirm that mobile service robots on wheeled chassis are the most numerous design of all realized applications, technical practice has filled with the diversity of their design solutions. The diversity of wheeled mobile service robots is mainly in the design of the wheeled chassis, the solutions range from single-wheeled to multi-wheeled concepts, from simple variants of the chassis layout to special or combined systems.

The purpose of the article is the design of a three-wheeled robot, which will include the derivation of a mathematical model, the construction of a simulation model and the creation of a model in CAD software. An important part of the robot analysis is a complete kinematic model of the mechanical system, which provides all the necessary kinematic quantities for both the dynamic model of the mechanical system (force application, link loading, sizing) and for control needs (synthesis of position and velocity controllers).

It is mainly about the position and orientation of the end working point in time and the corresponding position of the individual links of the mechanism. The next step was the overall design of the electronic system by appropriately selecting the electronic components and also creating the overall electronic circuitry. Finally, an experimental realistic model of the mobile robot was created from the simulation results.

Keywords: *mobile robot; simulation; mathematical model.*

Fig.: 8. References: 7.

Introduction. Nowadays, mobile wheeled robotics is an indispensable part, whether in industry such as AGV unmanned forklifts, which can communicate wirelessly with the control center of the line, or in everyday life, where service robots such as robotic vacuum cleaners represent a very large part. Inspection robots, which solve very specific problems, are also represented in countless numbers. One of these is the mobile inspection robot for finding explosive ordnance devices. Since this topic is very topical and the development is still progressing for this reason, the idea and the primary goal to design a total control, simulation and experimental prototype of a wheeled robot was conceived.

Mathematical model of a prototype mobile wheeled robot. The mathematical model of the prototype mobile wheeled robot consists of several subsystems. The kinematic model can be derived from the motion of the centre of gravity (COG) of the mobile wheeled robot, which is analogous to the motion of a material point in the plane when it moves in the plane given by its x, y coordinates and the rotation angle ω.

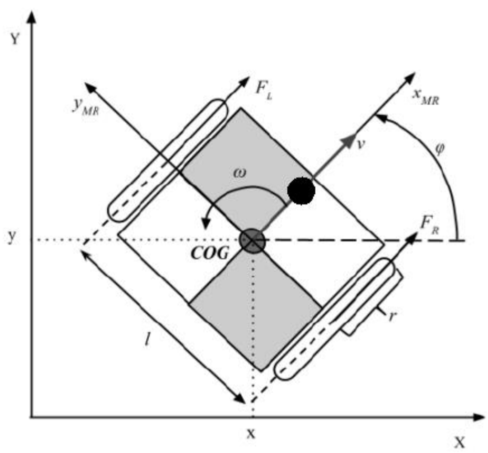

Fig. 1 Three-wheeled mobile robot

The motion of the mobile robot in the form of a forward velocity vector v is described by two components: the x-axis velocity (v_x) and the y-axis velocity (v_y). This combination of velocities forms the resulting kinematic model of the wheeled robot and it is:

$$v_x = v\cos\varphi \quad (1)$$

$$v_y = v\sin\varphi \quad (2)$$

$$\dot{\varphi} = \omega \quad (3)$$

So:

$$\begin{bmatrix}\dot{x}\\ \dot{y}\\ \dot{\varphi}\end{bmatrix} = \begin{bmatrix}\cos\varphi & 0\\ \sin\varphi & 0\\ 0 & 1\end{bmatrix}\begin{bmatrix}v\\ \omega\end{bmatrix} \quad (4)$$

The kinematic model of the mobile robot accepts inputs such as linear velocity (v) and angular velocity (ω). It processes these inputs to determine the position and rotation of the mobile robot in the [x, y, φ] plane.

The dynamic model of the mobile robot is an extension of the kinematic model presented earlier. This dynamic model, often referred to as the simple dynamic model, does not account for wheel slip, slippage, or frictional forces between the robot's wheels and the surface on which it moves. In this prototype model, we consider the forces (FR and FL) acting on the individual motors of the wheeled robot that are required for in-plane motion. The model includes parameters such as wheel path (l), robot mass (M), wheel moment of inertia (J_w), chassis moment of inertia (J), and wheel radius (r).

The forward velocity vector of the robot can be expressed using Newton's law, namely:

$$M\frac{\partial v}{\partial t} = F_R + F_L \quad (5)$$

The analogous rotational velocity (ω) with respect to the centre of gravity is then obtained by applying Newton's second law:

$$J\frac{\partial \omega}{\partial t} = \frac{1}{2}F_R - \frac{1}{2}F_L \quad (6)$$

To create the mathematical model, a feedback loop for dynamics suppression will need to be added, where based on the current angular velocity of the right ω_R and left $\omega_L$and the desired angular velocity of the right ω_{Rd} and left ω_{Ld}, the F_R and F_L forces that the robot's motors can exert will be computed. The feedback loop for suppressing the influence of the dynamics is constructed based on the equations which have the form:

$$F_{R/L} = P(\omega_{Rref\,/Lref} - \omega_{R\,/L})\; for\; |P\omega_{Rref\,/Lref} - \omega_{R\,/L}| < F_{max} \quad (7)$$

$$F_{R/L} = F_{max}sign(\omega_{Rref\,/Lref} - \omega_{R\,/L})\; for\; |P\omega_{Rref\,/Lref} - \omega_{R\,/L}| \geq F_{max} \quad (8)$$

The main task of the reduction is to recalculate the forward and angular velocity v, ω. The connection between the forward velocity (v), the angular velocity (ω) and the individual forward wheel velocities (v_R and v_L) can be given using matrix notation:

$$\begin{bmatrix}v\\ \omega\end{bmatrix} = \begin{bmatrix}0{,}5 & 0{,}5\\ 1/l & 1/l\end{bmatrix}\begin{bmatrix}v_R\\ v_L\end{bmatrix} \quad (9)$$

Multiplying the matrix gives an equation that expresses the circumferential velocities of the wheels v_R a v_L:

$$v_R = v + l/2\omega \quad (10)$$

$$v_L = v - l/2\omega \tag{11}$$

The circumferential velocity and angular velocity are defined by the equations:

$$v_R = r\omega_R \tag{12}$$

$$v_L = r\omega_L \tag{13}$$

Simulation model of a prototype wheeled robot. In this section, the individual subsystems that make up the overall robot simulation model are designed using block diagrams in Matlab/Simulink into which the previously derived equations have been inserted.

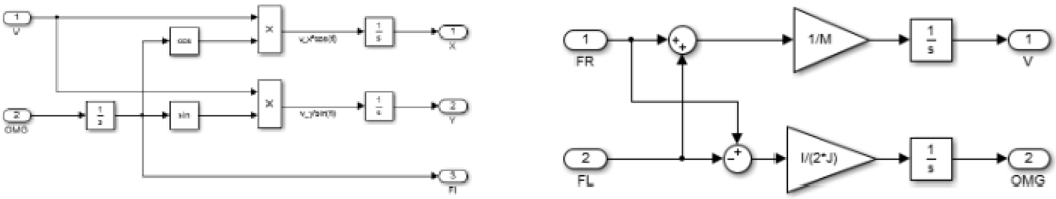

Fig. 2 Block diagram of the kinematic and dynamic subsystem of a three-wheeled robot

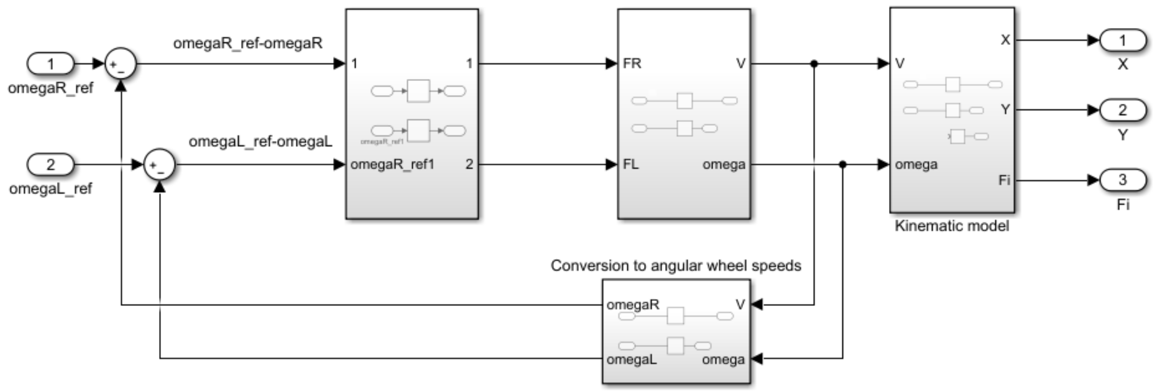

Fig. 3 Block diagram of the overall simulation model of the wheeled robot

Subsequently, the design of the three-wheeled robot was implemented in CAD software. The chassis will be a two-axle chassis with two driven independently steered wheels and one driven spherical(ball) wheel. The design of the prototype robot consists of seven parts.

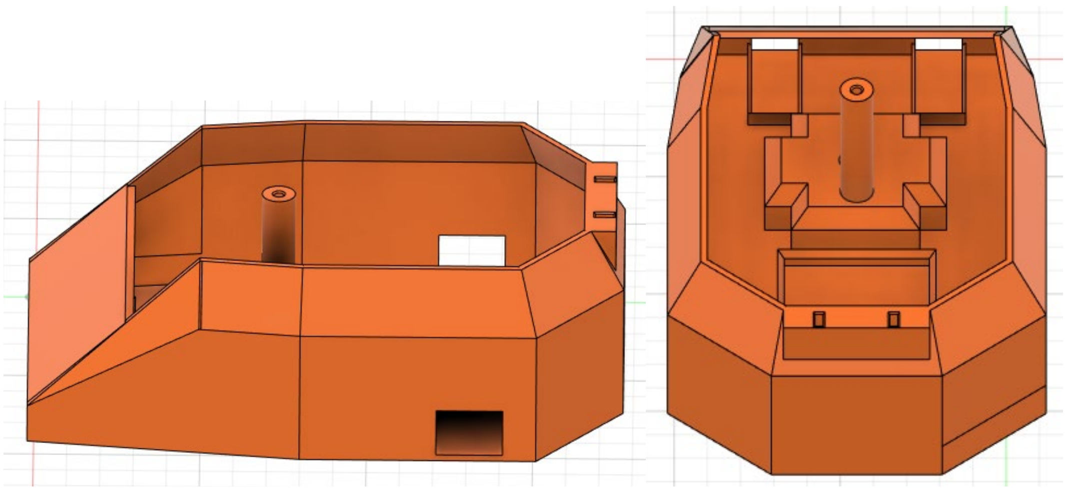

Fig. 4 Frame model

The next unit is the wheels, which consist of three separate parts, namely the inner disc, the outer disc and the tyre.

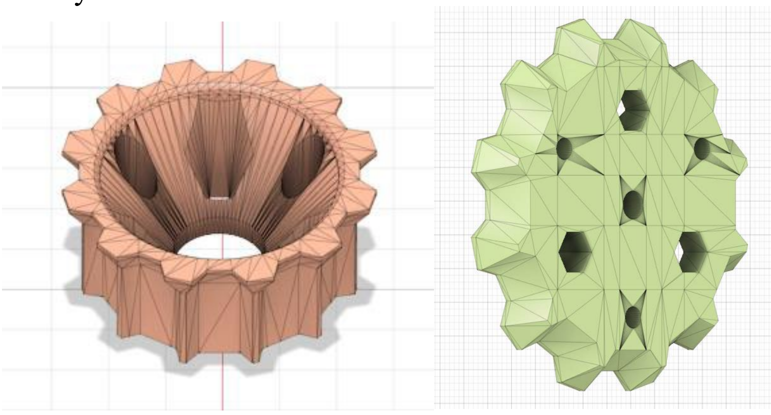

Fig. 5 Outer and inner disc model

Fig. 6 shows the completed 3D model of the prototype mobile wheeled robot.

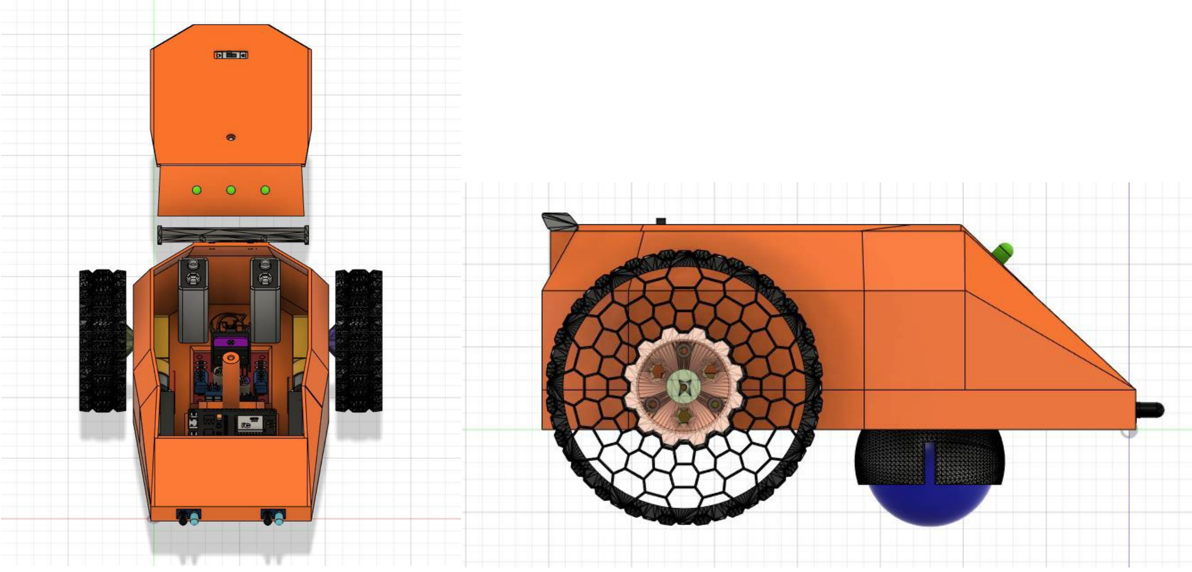

Fig. 6 Completed 3D model of a prototype mobile wheeled robot

The overall dimensions of the prototype wheeled robot are: length = 192mm, width = 176mm and height = 105mm.

Design of the electronic part of the prototype wheeled robot. The following section presents the overall design of the electronic subsystem of the prototype wheeled robot. Two DC motors with an all-metal gearbox were chosen to drive the wheels. For the control of the motors, the L298N H-bridge was chosen with the capability of controlling two motors. Two infrared sensors were chosen for obstacle sensing and mainly to prevent the robot from crashing. A small three-position switch was chosen to switch on the robot. To signal the robot switching on, 3 LEDs were chosen, which are connected in series, and also one resistor. The power supply for the drive part consists of one 9V battery and two 1.5V batteries connected in series. Two 1.5V batteries are used as the external power supply for the control unit. The main component for the prototype robot is the control unit. ESP 32 WROOM was chosen as the control unit.

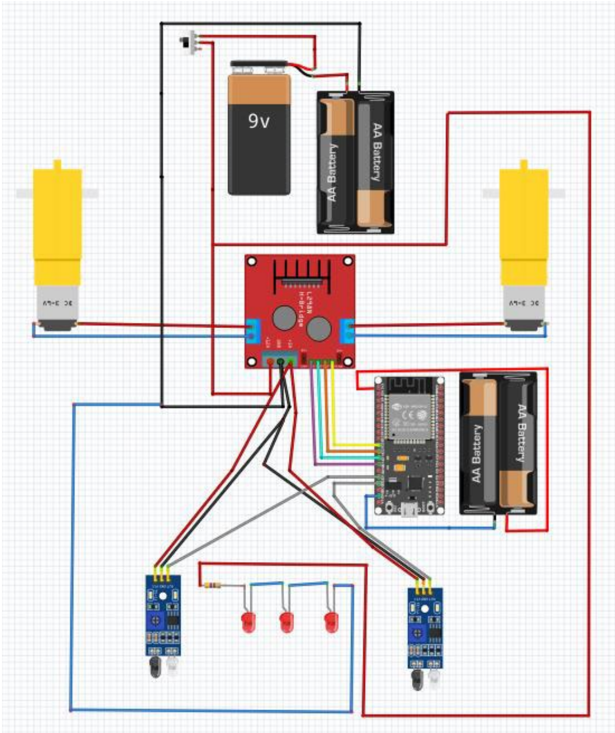

Fig. 7 Electronic circuit design

In Fig.8, a functional three-wheeled mobile robot is assembled.

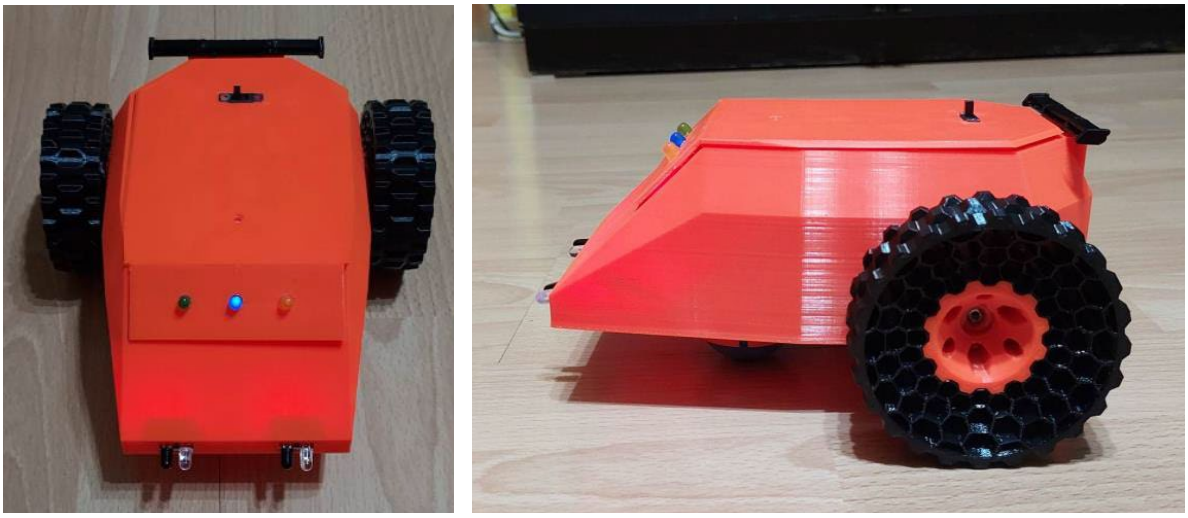

Fig. 8 Real model of a mobile wheeled robot

Conclusion. This paper deals with the design of a three-wheeled mobile robot. A mathematical model of the wheeled robot has been constructed, from which the actual design of the simulation model of the wheeled robot consists. The experimental model of the wheeled robot has been designed and this design has been carried out in CAD software where the overall design model of the prototype wheeled robot has been created. After the simulation and experimental design, the overall design of the electronic system was carried out by selecting the correct electronic components and also creating the overall electronic circuitry. As the last step, a functional real robot model was created. Design of the control algorithm for the prototype wheeled robot.

Acknowledgements

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ПРОЕКТ ФУНКЦІОНАЛЬНОЇ МОДЕЛІ ТРИКОЛІСНОГО МОБІЛЬНОГО РОБОТА

Мобільні колісні роботи є однією з найпоширеніших на сьогоднішній день груп сервісних роботів. Простота їхньої конструкції та здатність краще долати складну місцевість робить їх передовими. На практиці можна зустріти різноманітні мобільні колісні роботи, які відрізняються один від одного кількістю та розташуванням коліс, різноманітністю конструкції або підвіскою коліс.

Сучасна статистика підтверджує, що мобільні сервісні роботи на колісних шасі є найчисленнішими з усіх реалізованих додатків, технічна практика наповнила різноманітністю їх конструктивних рішень. Різноманітність колісних мобільних сервісних роботів полягає в основному в конструкції колісних шасі, рішення варіюються від одноколісних до багатоколісних концепцій, від простих варіантів компонування шасі до спеціальних або комбінованих систем.

Метою статті є проектування триколісного робота, що включатиме виведення математичної моделі, побудову імітаційної моделі та створення моделі в программі CAD. Важливою частиною аналізу робота є повна кінематична модель механічної системи, яка надає всі необхідні кінематичні величини як для динамічної моделі механічної системи (прикладення сили, навантаження ланки, розмір), так і для потреб керування (поєднання положення і регуляторів швидкості). Кінематичну модель можна вивести з руху центру тяжіння (COG) мобільного колісного робота, який аналогічний руху матеріальної точки в площині, коли вона рухається в площині. Йдеться головним чином про положення та орієнтацію кінцевої робочої точки в часі та відповідне положення окремих ланок механізму.

Окремі підсистеми, які складають загальну імітаційну модель робота, розроблені за допомогою блок-схем у Matlab/Simulink, у які задано попередньо отримані рівняння.

Наступним кроком був загальний дизайн електронної системи шляхом відповідного вибору електронних компонентів, а також створення загальної електронної схеми. Нарешті, за результатами моделювання була створена експериментальна реалістична модель мобільного робота.

Ключові слова: *мобільний робот; моделювання; математична модель.*
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