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SIMULINK BASED DYNAMIC MODEL FOR MECANUM DRIVE AUTONOMOUS MOBILE PLATFORMS CONSIDERING FRICTION FORCES

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Abstract: *This paper provides a detailed description about how to develop and validate a model concerning the dynamics of a mobile robot using Matlab and Simulink. The fundamental component in the development of the model is the import of a 3D CAD model from SolidWorks into Simulink Simscape. The virtual model to simulate the entire dynamics of the mobile robot is based on a Mecanum wheels locomotion principle. The study encompasses an extensive review of existing dynamic models, considering frictional forces, as well as the design and kinematic modeling of the actuation systems for omnidirectional drive configuration. Using SolidWorks, a 3D virtual representation of the robots was developed and integrated into Simulink-Simscape to develop the dynamic model. Mathematical model for robot kinematics and controls was rigorously formulated within Simulink, employing the Jacobian matrix and its transpose to decompose resistive forces at the motor shafts into inertial and frictional components, enabling accurate electrical current monitoring during robot motion. The paper also introduces a characteristic block diagram for assessing DC motor electrical current consumption, crucial for analyzing the robots' operational efficiency. An important aspect of this research lies in the experimental validation of the dynamic model through real-time measurements of electrical current on a mobile platform, affirming its accuracy and practicality. This combined exploration of dynamic modeling and resistive forces analysis represents a significant contribution to the field of autonomous mobile robotics, promising substantial advancements in energy-efficient operations and driving capabilities.*

Key words: *dynamic model, Mecanum wheels, friction forces, Simulink-Simscape.*

1. INTRODUCTION

The present work aims to outline the steps taken in the development of an algorithm to determine the energy consumption efficiency of a mobile platform with differential locomotion. Considering that robotics is in a continuous state of development, the energy analysis of omnidirectional mobile robots arouses significant interest among researchers.

Such platforms offer increased versatility and adaptability, facilitating effective navigation across different terrains and operational contexts [1-4].

The study focuses on the enhanced maneuverability offered by Mecanum wheels, boosting the platform's operational capabilities [4-6]. It aims to create a complete dynamic model capturing the resistant torques and forces acting on Mecanum-wheeled platforms. The created model takes into account factors like wheel types, the mass of the robot and the mass of the wheels, static forces acting onto the robot when it is not moving, moments of inertia, and friction forces. Understanding these dynamics is vital for both the design and control of mobile platforms [7-8], providing critical insights into their performance across different operational scenarios.

Stefek in [9] categorizes mobile robots based on Mecanum and Caster wheels. Taheri and Bayar [10-11] developed a kinematic model for omnidirectional mobile robots under sliding conditions. Cerkala created a control and dynamic model for Mecanum-wheeled platforms using MATLAB [12]. However, these studies predominantly focus on kinematic models, overlooking comprehensive dynamic

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models that incorporate resistive frictional forces [13-15]. This study aims to bridge this gap by developing such a model.

The primary objective is to create a dynamic model for omnidirectional mobile robots with Mecanum wheels. This model will account for the robot's mass, static forces, inertia, and frictional forces acting on the platform. The dynamic model will be constructed in Simscape Simulink to accurately simulate the physical system. Initially, a 3D model of the mobile platform will be developed in SolidWorks and then imported into Simscape to generate a multi-body representation of the system.

Friction forces will be integrated into the dynamic model to accurately capture the resistive forces during platform motion. This includes both static and dynamic friction and specific friction coefficients. The kinematic model of the four-wheel drive mobile robot will be incorporated into the dynamic equations to ensure a comprehensive understanding of the motion dynamics.

To validate the proposed dynamic model, empirical data will be collected through physical experiments on a prototype of the mobile platform. These experiments will provide real-world data to verify the accuracy and reliability of the dynamic model, ensuring it reflects the actual performance of the platform under various operational conditions. This comprehensive approach will offer deeper insights into the dynamics of Mecanum-wheeled mobile robots and contribute significantly to the field of mobile robotics.

2. MATERIALS AND METHODS

Creating a mobile robot with four-wheel drive involves determining the necessary torque to move the entire platform. This calculation must take into account various critical factors such as the total mass, inertia, and wheel count. To accurately assess the needed torque for the four-wheel drive mobile robot, understanding its kinematics and dynamics is crucial. This understanding comes from exploring the robot's mathematical model, which includes both its static and dynamic characteristics.

The entire mass of the mobile platform, including the robot wheels is 3 Kg. Based on this input data the gravity force acting onto the platform was determined:

$$G = m_t \cdot g \tag{1}$$

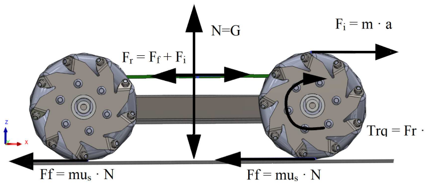


Fig. 1. Resistive forces identification for a mobile robot

The friction force F_f is computed using the equation (2):

$$F_f = \mu_s \cdot N \tag{2}$$

were: N = G. The inertia of the robot is computed using the below equation:

$$F_i = m \cdot a \tag{3}$$

where: a is the determined knowing the law of variation of the robot's velocity over time. This is an imposed law of variation for the robot. The maximum absolute value for the acceleration is a = 1[m/s^2].

The total sum of the resistance forces is:

$$F_r = F_f + F_i \tag{4}$$

The total inertia of the wheels is determined using equation (5).

$$Tq_i = n_w \cdot w_i \tag{5}$$

where: n_w is the number of robot wheels, w_I is the wheel inertia. The inertia of the wheel is determined using:

$$w_i = I \cdot \varepsilon \tag{6}$$

Because the wheel has a cylinder shape:

$$I = \frac{1}{2} \cdot m_w \cdot r^2 \tag{7}$$

where: m_w is the wheel mass, I is the wheel moment of inertia, $\varepsilon = \frac{a}{r}$ is the angular acceleration of the wheel, r is the wheel radius.

The necessary torque needed for driving the robot is computed using:

$$Tq_t = Tq_r + Tq_i \tag{8}$$

$$Tq_r = F_r \cdot r \tag{9}$$

where: Tq_t represents the total torque, Tq_r is the torque for linear movement.

To compute the necessary mechanical power one, can use expression (10):

$$P_m = n \cdot Tq_t \tag{10}$$

where: n is the wheel velocity measured in [rpm], $n = (\omega \cdot 60)/(2 \cdot \pi)$, ω is the angular velocity of the wheel $\omega = v/r$.

3. KINEMATIC MODELS FOR MECANUM WHEELED MOBILE PLATFORMS

In order to create an accurate and reliable virtual dynamic model for a mobile robot, which later allows for the analysis of resisting forces during its movement along an imposed trajectory, it is imperative to include both the components related to motion and those that impose that motion on the system.

This integration of kinematic and dynamic modeling enables the simulation of the robot's behavior under various conditions, ultimately leading to better control strategies and improved performance.

3.1 Four-Wheel Mecanum drive Locomotion

To understand the locomotion capability of a mobile robot with Mecanum wheels one must resolve and use the mobile robot kinematics.

Furthermore, the study of Mecanum wheel kinematics will allow for the development of efficient driving algorithms and trajectory generation techniques for mobile robots. It is important to note that Mecanum wheels enable the robot to move in any direction, making them highly maneuverable. These equations consider factors such as the wheel slip, roller angle, and the robot's position and orientation.

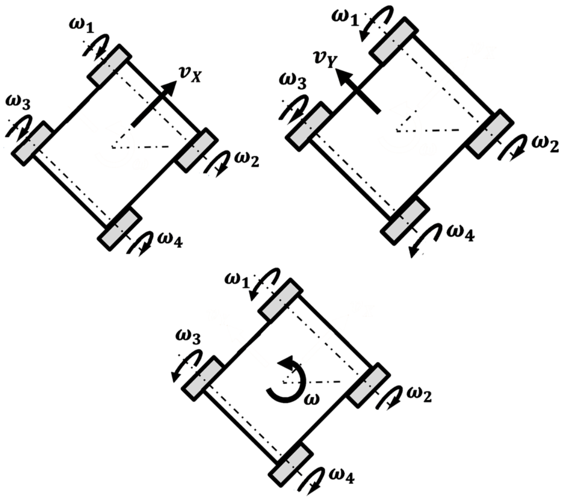


Fig. 2. Mecanum wheeled mobile robot kinematics

To describe this relationship mathematically, one can use the following kinematic equations:

The direct kinematics equations for Mecanum drives locomotion are presented in (11):

$$\begin{bmatrix} v_X \\ v_Y \\ \omega \end{bmatrix} = \frac{R}{4} \begin{bmatrix} 1 & 1 & 1 & 1 \\ -1 & 1 & 1 & -1 \\ -\frac{2}{(L_X + L_Y)} & \frac{2}{(L_X + L_Y)} & -\frac{2}{(L_X + L_Y)} & \frac{2}{(L_X + L_Y)} \end{bmatrix} \begin{bmatrix} \omega_1 \\ \omega_2 \\ \omega_3 \\ \omega_4 \end{bmatrix} \tag{11}$$

The Inverse kinematics equations are presented in (12):

$$\begin{bmatrix} \omega_1 \\ \omega_2 \\ \omega_3 \\ \omega_4 \end{bmatrix} = \begin{bmatrix} 1 & -1 & -(L_X + L_Y)/2 \\ 1 & 1 & (L_X + L_Y)/2 \\ 1 & 1 & -(L_X + L_Y)/2 \\ 1 & -1 & (L_X + L_Y)/2 \end{bmatrix} \begin{bmatrix} v_X \\ v_Y \\ \omega \end{bmatrix} \tag{12}$$

Using the Jacobian matrix for joint torques decomposition. The Jacobian matrix is a powerful tool in multivariable calculus and related fields, offering insights into the local behavior of functions and the relationships between their variables.

The transpose matrix of the Jacobian is crucial in mechanics and robotics. It is particularly important for understanding the relationship between input and output forces [14]. This matrix transpose is used to describe how applied forces translate into resulting movements within robotic systems.

In robotics, the Jacobian matrix is used to transform velocities from the joint space (the actuator space) into velocities in the operational space (e.g., the position and orientation of the end-effector). Conversely, the transpose of the Jacobian matrix can be used to transform forces in the operational space back into the joint space.

In mechanics, if we have a Jacobian matrix J mapping joint velocities to end-effector velocities, then Jt (the transpose of the Jacobian) maps forces applied at the end-effector back to forces/torques in the joints. This means that if we know the forces applied at the end-effector, we can calculate the corresponding forces or torques required at each joint of the robot.

To create a model to simulate the dynamics for the mobile platform the Jacobian transpose matrix is needed for reducing the resistant forces and the inertias of the robot body to resistant torque at the driving wheels.

Jacobian for Mecanum drive configuration is presented in (13).

$$J = \begin{bmatrix} \frac{r}{4} & \frac{-r}{4} & \frac{-r}{2\cdot(L_x+L_y)} \\ \frac{r}{4} & \frac{r}{4} & \frac{r}{2\cdot(L_x+L_y)} \\ \frac{r}{4} & \frac{r}{4} & \frac{-r}{2\cdot(L_x+L_y)} \\ \frac{r}{4} & \frac{-r}{4} & \frac{r}{2\cdot(L_x+L_y)} \end{bmatrix} \qquad (13)$$

The transpose Jacobian matrix:

$$J^t = \begin{bmatrix} \frac{r}{4} & \frac{r}{4} & \frac{r}{4} & \frac{r}{4} \\ \frac{-r}{4} & \frac{r}{4} & \frac{r}{4} & \frac{-r}{4} \\ \frac{-r}{2\cdot(L_x+L_y)} & \frac{r}{2\cdot(L_x+L_y)} & \frac{r}{2\cdot(L_x+L_y)} & \frac{-r}{2\cdot(L_x+L_y)} \end{bmatrix} \qquad (14)$$

4. FRICTION FORCES

In order to create a dynamic model of a mobile robot as accurately as possible, the frictional forces at the wheels must be taken into account. Very few studies address this factor. If the friction during the movement of the mobile robot is considered, a robust command and control system for the robot can be developed.

The friction forces at the wheels of the mobile robot are presented in a simplified version in figure 3. A classic model representing the friction force during wheel rotation, $\mathbf{F_{fr}}$, can be created using the general friction force equation:

$$F_{fr} = -\mu_r \cdot N \cdot \operatorname{sgn}(v_X), \qquad (15)$$

where μ_r is the notation used for the rolling friction coefficient. The normal force on the running surface is **N**, which takes into account the mass of the mobile robot. The distribution of the normal force on the four driving wheels must be considered, as it is very important. When the mobile robot rotates around a central point at the level of the wheels, two types of frictional forces will appear. These frictional forces have two main components: longitudinal frictional forces and lateral frictional forces that occur during the rotation process. These forces are crucial for the energy efficiency of the mobile robot during movement. When the rotation speed of the left wheels differs from that of the right wheels, a frictional force in the lateral direction, $\mathbf{F_{fl}}$, occurs during rotation. The lateral frictional force is highly dependent on the steering angle of the wheels and has a strong influence on wheel slippage on the running surface.

The lateral frictional force component is very similar to sliding friction. In this case, one can assume that $\mathbf{F_{fl}}$ is:

$$F_{fl} = -\mu_s \cdot N \cdot \operatorname{sgn}(v_Y) \qquad (16)$$

One can consider that during rotational movement the total friction force $\mathbf{F_t}$ during is the sum of the above-described friction forces:

$$F_{ft} = F_{fr} + F_{fl} \qquad (17)$$

During the rotation of a four-wheel drive robot, both rolling friction and lateral (sliding) friction are involved.

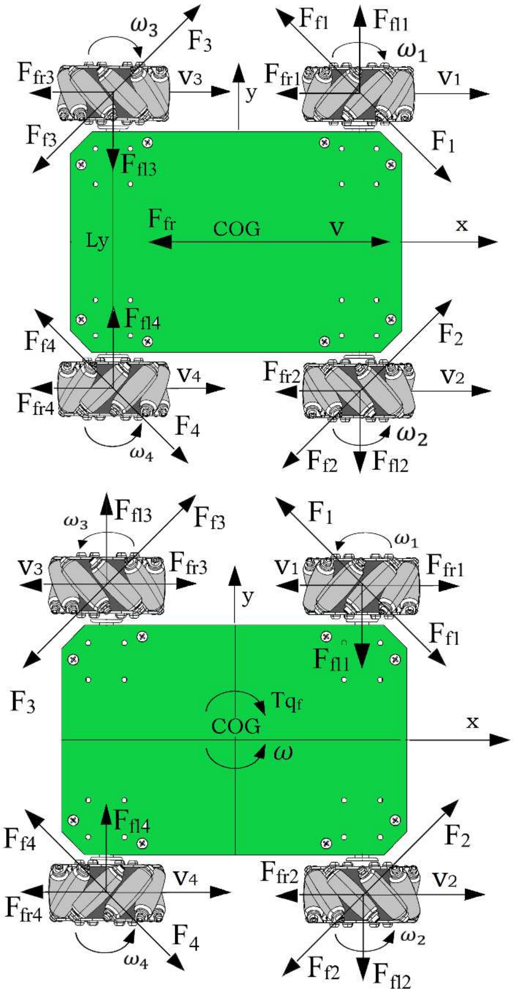


Fig. 3. Friction forces for Mecanum wheeled mobile robot

deformation of the wheels and the surface at the point of contact, whereas sliding friction is due to the lateral motion of the wheels during rotation. To integrate both types of friction into the mathematical model, we need to consider these aspects separately.

Modified model with rolling and lateral friction generates the total friction Torque for rotation:

$$\mathrm{Tq_f} = -\,\mathrm{F_{ft}} \cdot \mathrm{b} \cdot \mathrm{sgn}(\omega) \quad (18)$$

$$\mathrm{Tq_f} = -\,(\mathrm{F_{fr}} + \mathrm{F_{fl}}) \cdot \sqrt{\frac{\mathrm{Lx}^2}{2} + \frac{\mathrm{Ly}^2}{2}}\,\mathrm{sgn}(\omega) \quad (19)$$

where: **b** represents the distance from the center of the robot, which is also the center of rotation, to the point where the wheels contact the running surface.

To use appropriate friction coefficients, an analysis of the specialized literature was conducted. For the laboratory running surface, the coefficients μ_r = 0.05 and μ_s = 0.3 were chosen. It is extremely important to integrate both rolling and sliding friction into the mathematical model to faithfully replicate the movement process of the Mecanum-wheeled mobile robot. These two components are crucial for determining friction torques, distinguishing between linear and rotational movements.

Additionally, the angle of the rollers α must be considered when calculating the sliding friction. The rolling friction force acting on a Mecanum wheel is determined as follows:

$$\mathrm{F_{fr}} = -\mu_r \cdot \mathrm{N} \cdot \cos(\alpha) \cdot \mathrm{sgn}(v_X) \quad (20)$$

where: α is the angle created by the rollers and spinning direction of the wheel.

The component of the friction force for sliding regarding the Mecanum wheel can be determined using:

$$\mathrm{F_{fl}} = -\mu_s \cdot \mathrm{N} \cdot \sin(\alpha) \cdot \mathrm{sgn}(v_Y) \quad (21)$$

The direction is determined by the wheel's velocity (**v**) relative to the ground, projected along the roller in a parallel manner. The key advantage of the Mecanum wheel lies in its rollers, which convert sliding forces into rotational motion. Consequently, the sliding force is influenced by the rolling friction of the roller. This configuration of robot wheels allows for smooth motion without any net lateral direction friction force, making it possible to move the vehicle in any direction with precise control.

$$\mathrm{F_{ft}} = \sum_{i=1}^{n} \mathrm{F_{fri}} + \sum_{i=1}^{n} \mathrm{F_{fli}} \quad (22)$$

where: n – is the number of wheels.

For forward movement $\sum_{i=1}^{n} \mathrm{F_{fli}} = 0$ so:

$$\mathrm{F_{ft}} = \mathrm{F_{fr}} \quad (23)$$

For Lateral movement - Lateral direction friction force longitudinal direction friction forces cancel each other out. For side-to-side movement $\sum_{i=1}^{n} \mathrm{F_{fri}} = 0$ so:

$$\mathrm{F_{ft}} = \mathrm{F_{fl}} \quad (24)$$

The friction rotational movement has dual components. The friction in this case contains a longitudinal and lateral component. So $\sum_{i=1}^{n} \mathrm{F_{fli}}$ and $\sum_{i=1}^{n} \mathrm{F_{fri}}$ are different from zero. Lateral friction forces in Mecanum wheels generate rotational movement of the wheel's rollers around their own axes. As a result, the behavior of these lateral friction forces is akin to rolling friction. Therefore, in this context, the friction force can be approximated to:

$$\mathrm{F_{ft}} = \mathrm{F_{fr}} + \mathrm{F_{fl}} \quad (25)$$

Total friction Torque for rotation:

$$\mathrm{Tq_f} = \mathrm{F_{ft}} \cdot \mathrm{b} \quad (26)$$

$$\mathrm{Tq_f} = -\,\mu_r \cdot \mathrm{N} \cdot \sqrt{\frac{\mathrm{Lx}^2}{2} + \frac{\mathrm{Ly}^2}{2}} \cdot \mathrm{sgn}(\omega) \quad (27)$$

To conclude, the friction properties of Mecanum wheels are intricate and diverse, playing a vital role in enabling robots to move in any direction. The wheel design and materials, as well as the surface texture, greatly affect the robot's maneuverability and control.

5. DYNAMIC MODEL FOR MECANUM WHEELED MOBILE PLATFORMS

To be able to create the dynamic model characteristic for the mobile robot equipped with Mecanum wheels when moving on a pre-defined trajectory one can use the Simulink environment. The dynamic model is derived from a three-dimensional virtual assembly created in SolidWorks and is comprehensively developed within the Matlab-Simulink. The tridimensional virtual model of the mobile robot is presented in figure 4. The dynamic model incorporates several critical components:

1. Kinematic Actuation Module: This module within Simulink governs the movement of the kinematic elements of the mobile platform, facilitating various actions based on provided commands and inputs.

2. Transpose Jacobian Matrix Module: This module computes the transposed Jacobian matrix of the Mecanum wheeled robot, offering crucial insights into the relationship between joint torques and the resistive forces acting on the robot's structure.

3. Friction Force Integration Module: This module integrates frictional forces into the dynamic model, ensuring a realistic simulation of the mobile platform's motion.

4. Simscape Integration: The entire dynamic model is developed within the Simulink Simscape environment, providing a robust and versatile framework for simulating and analyzing the platform's behavior.

The block diagram of the actuation system of the mobile robot is shown in figure 5.

The block diagram of the dynamic model is depicted in figure 6.

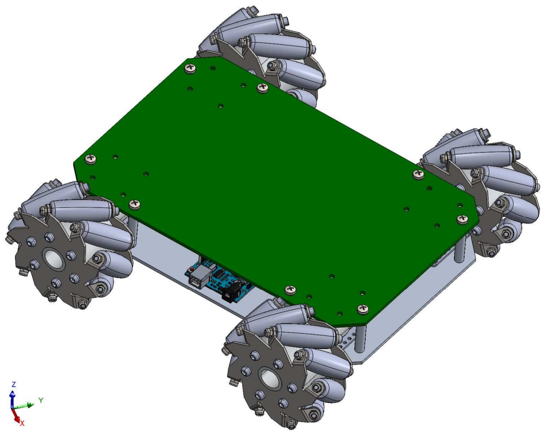


Fig. 4. 3D CAD model of Mecanum wheeled mobile robot

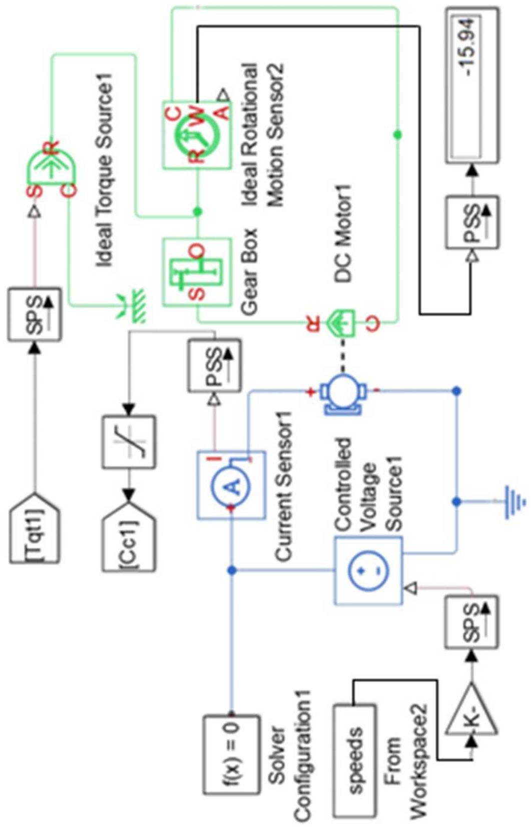


Fig. 5. Simulink Simscape current sensing diagram

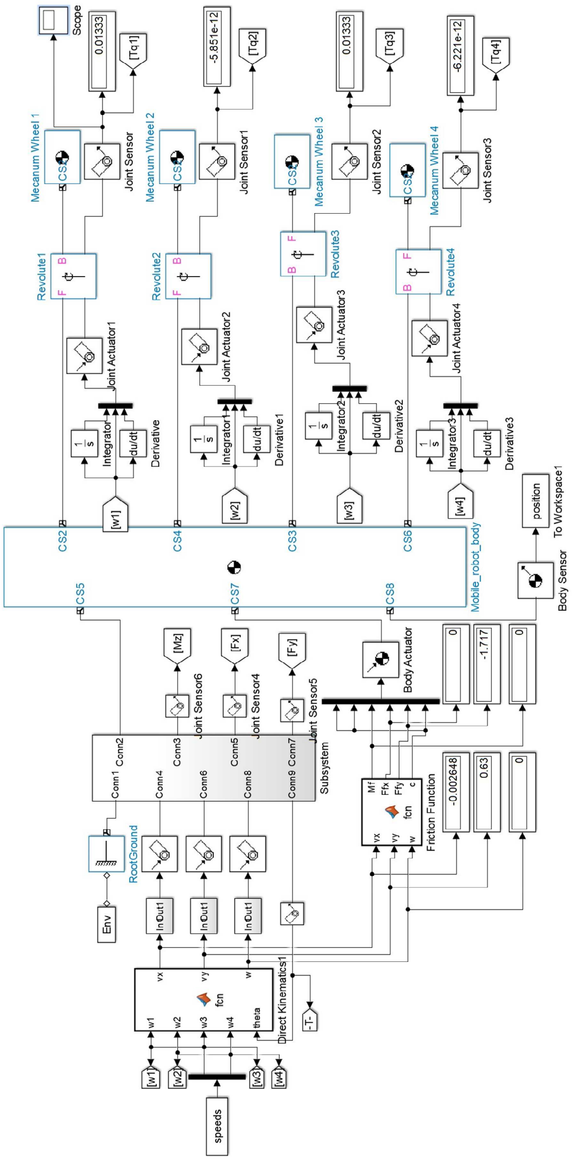
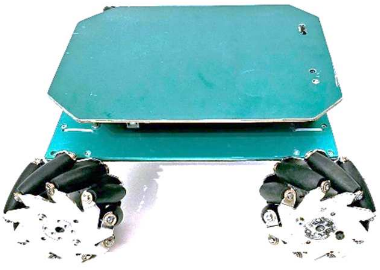


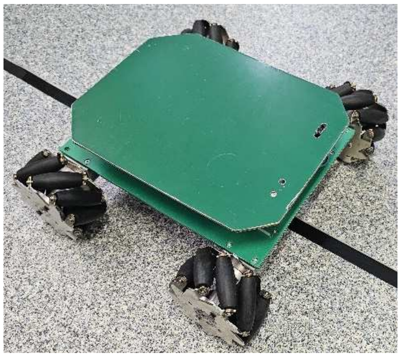
Fig. 6. Simulink Simscape dynamic model of Mecanum wheeled mobile robot.

6. PHYSICAL MODEL

The mobile robot used for validating the dynamic model is presented in figure 7.



a.



b.

Fig. 7. Physical model of Mecanum wheeled mobile robot.

In figure 8 the electronic diagram for the mobile robot is presented.

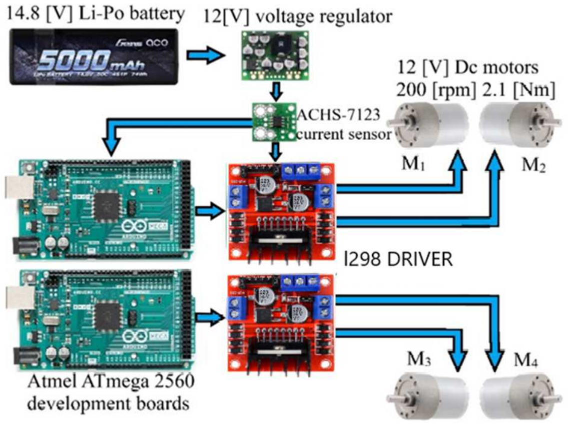


Fig. 8. Electronic diagram of the mobile robot.

The robot's command and control system is built utilizing two microcontroller development boards powered by the ATMega 2560 processor. For managing movement, the robot uses two L298 H-bridge motor controllers. These controllers function within a voltage spectrum of 5.5 to 40 V, delivering a continuous current of 3 A per motor, with a peak capability of 5 A. They support high PWM frequencies to minimize operational noise and are equipped with several protection features including reverse-voltage protection, thermal shutdown, and short-circuit safeguards.

The robot is actuated by four 12V DC motors, each capable of reaching a top rotational speed of 200 RPM. The power system consists of a 14.8V Li-Po battery paired with a 12V, 15A voltage regulator, ensuring a steady and adequate power supply for both the motors and electronic components.

To track power usage, an ACHS-7123 current sensor is incorporated into the electric circuit. This sensor can handle bidirectional current input up to 30 A and delivers an analog voltage output that is proportional to the current. The sensor features low internal resistance (~0.7 mΩ), electrical isolation up to 3 kV RMS, a bandwidth of 80 kHz, high precision, and an operational temperature range from -40°C to 110°C.

7. EXPERIMENTAL MEASUREMENT

The figure 9 represents the current consumption for the mobile robot during forward movement. The measurements were taken during four trials of the robot's movement using Mecanum wheels.

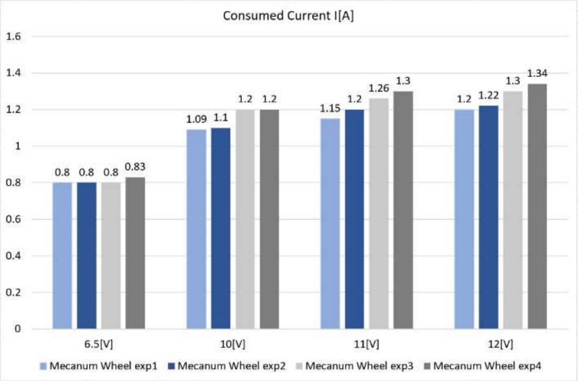


Fig. 9. Consumed current for forward movement.

The graph shows the current consumed at four different supply voltages: 6.5V, 10V, 11V, and 12V. At 6.5V, the current consumption is relatively low, with values recorded at around 0.8A for each of the four experiments. When the voltage is increased to 10V, there's a slight rise in current consumption, with values just above 1A for all trials. At 11V, the current consumption is higher, showing a range between 1.15A and 1.3A across the experiments. Finally, at 12V, the consumption continues to increase, with measurements ranging from 1.21A to 1.34A.

In figure 10 the current consumption of the mobile robot equipped with Mecanum wheels during rotational movement, as measured by the current sensor, is presented. At 6.5V, the current consumption is consistently 0.8A for all experiments, which indicates a uniform power requirement for the Mecanum wheels at this voltage.

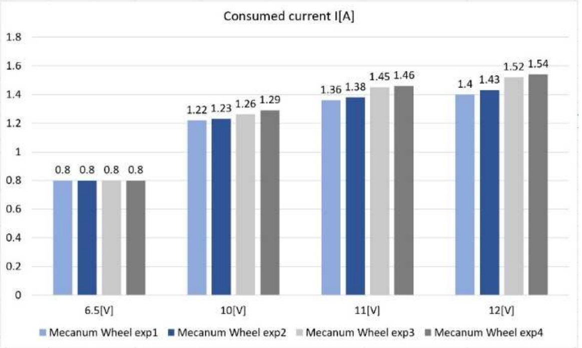


Fig. 10. Consumed current for rotational movement.

As the voltage increases to 10V, there is a gradual increase in current consumption with the values ranging from 1.22A to 1.29A. At 11V, the current consumption is slightly higher, with values between 1.36A and 1.46A. At the highest voltage of 12V, the current values range from 1.4A to 1.54A, showing the largest consumption among the tested voltages.

The data shows that the robot's rotational movement requires more power as the voltage increases, which is a typical characteristic of electric motors and their power consumption patterns.

The current consumption at different voltages for four separate experiments involving lateral motion for the Mecanum wheeled robot is presented in figure 11.

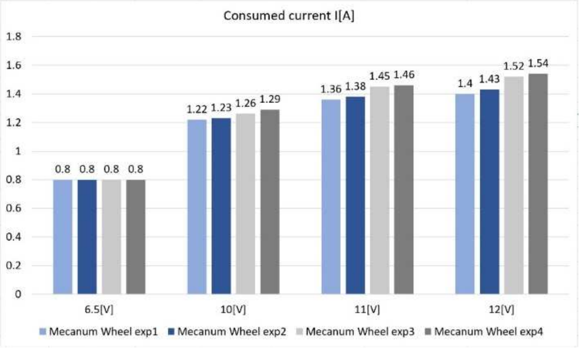


Fig. 11. Consumed current for lateral movement.

For 6.5V, all four experiments show a current consumption below 1A, with the bars labeled with exact values of 0.89A for exp1 and exp2, and 0.92A for exp3 and exp4. At 10V, the current consumption for all experiments is between 1.4A and 1.45A, with each bar labeled with precise values for each experiment. For

11V, the current consumption is slightly higher, with values at 1.55A and 1.65A for experiments 1 and 2, and 1.6A and 1.67A for experiments 3 and 4. At 12V, the current consumption further increases, reaching 1.7A for experiment 1, 1.75A for experiment 2, 1.6A for experiment 3, and 1.8A for experiment 4. The bar chart illustrates that the consumed current for the Mecanum wheel increases with the voltage. across the four different experiments. At the lowest voltage of 6.5V, the current consumption is below 1A for all experiments. As the voltage rises to 10V, 11V, and then to 12V, the consumed current increases accordingly.

Comparison between Forward - Backward and Lateral movement for Mecanum wheels design: Comparing the two graphs, which represent the current consumption of Mecanum wheels at different voltages for a robot, one can note the following differences and similarities: The first graph, figure8, representing the forward and backward movement, shows a less pronounced increase in current consumption, with values ranging from approximately 0.8A at 6.5V to about 1.34A at 12V. The second graph, figure 10, representing lateral movement, demonstrates a more considerable increase, with values starting around 0.89A at 6.5V and rising to 1.8A at 12V. The second graph shows greater consistency between the experiments at higher voltages, while the first graph exhibits more variability between experiments at the same voltage levels. Both graphs display a general trend of increasing current consumption with increasing voltage, but the second graph indicates a steeper increase. Additionally, the differences could also be attributed to specific design or operational factors unique to each set of experiments. The results presented in the graphs indicate that the current consumption for lateral movement of a robot using Mecanum wheels is higher than for forward and backward movement. Since current consumption can be correlated with the force required to move the robot, it can be inferred that the forces of friction encountered during lateral movement are greater than those encountered during forward and backward movement. This conclusion is consistent with the understanding that Mecanum wheels, due to their unique design and the way they interact with the surface during lateral movement, may experience more resistance, hence greater frictional forces, compared to more traditional linear movements, as presented in equations (25).

7.1 Validating the Simulink dynamic models of the robot

Measurements were taken for various directions of movement of the mobile robot. The dynamic model in Simulink, as mentioned earlier, is necessary when it comes to optimizing the robot's driving for specific missions in robot's workspace.

Results obtained for forward movement, are presented in figure 12 and figure 13.

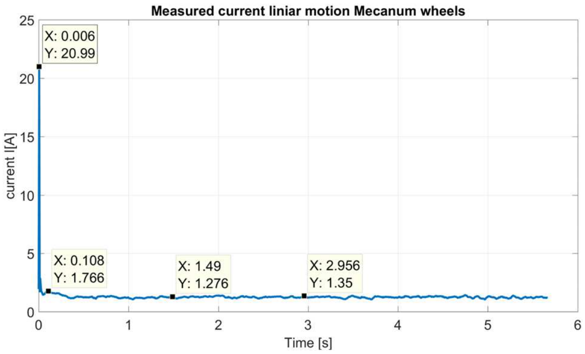


Fig. 12. Measured current for forward movement experimental.

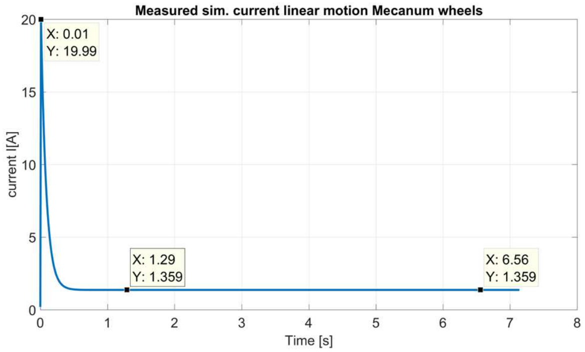


Fig. 13. Measured current for forward movement Simulink.

Results obtained for lateral movement, are presented in figure 14 and figure 15.

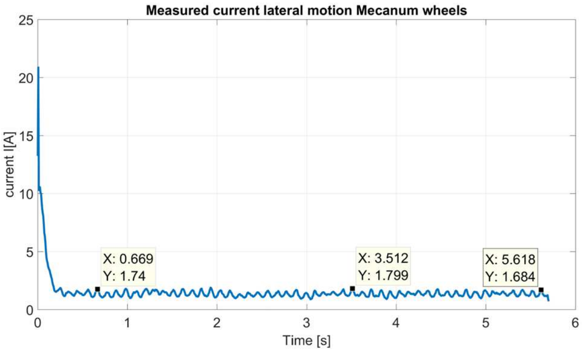


Fig. 14. Measured current for lateral movement experimental.

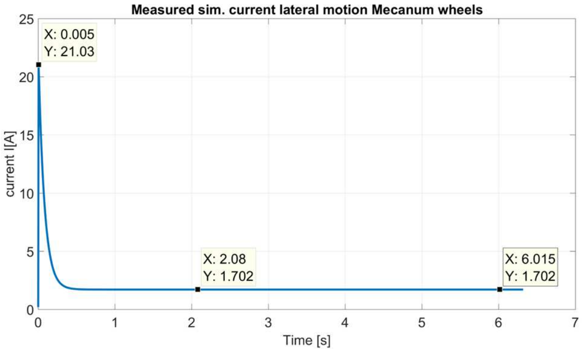


Fig. 15. Measured current for lateral movement Simulink.

Results obtained for rotational movement, are presented in figure 16 and figure 17.

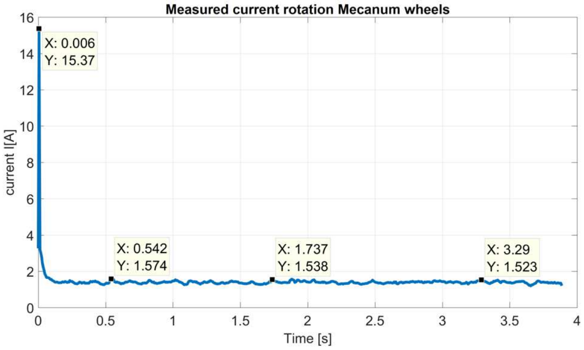


Fig. 16. Measured current for rotational movement experimental.

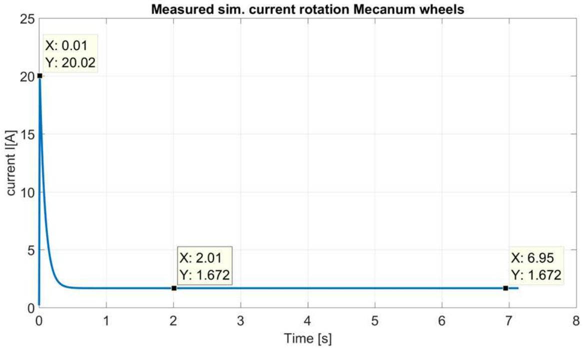


Fig. 17. Measured current for rotational movement Simulink.

8. CONCLUSIONS

Upon comparing the graphs, minor differences are observed between the real-world data and the simulation outcomes. The general trends and cyclic nature of the current consumption remain consistent across both experimental and simulated data, with spikes aligning at identical points along the trajectory. This alignment suggests that the simulation effectively reflects the system's overall dynamics.

These observations imply that the simulation model, successfully captures the critical dynamics of the robot's current consumption during operation, thereby confirming the model's value in predicting the robot's behavior. This comparison also serves as constructive feedback for further refining the simulation to more closely resemble actual performance.

From the experimental data collected, additional insights related to the dynamic model created in Simulink can be inferred. These insights conduct to the experimental validation, consideration of frictional forces, among other significant elements.

The research successfully met its goal to construct and experimentally validate a dynamic model of a mobile platform in Simulink. This model precisely accounts for resistive forces, including friction, acting on the platform.

A notable feature of the model is its attention to frictional forces, vital for creating realistic simulations of platform movement. By incorporating these forces, the model can predict the platform's behavior under various conditions with greater accuracy.

The experimentally validated dynamic model becomes an invaluable asset for developing sophisticated driving algorithms for mobile platforms. It enables the simulation and evaluation of diverse motion patterns to efficiently reduce energy consumption. Such adaptability is crucial for planning the platform's movement and to meet varied operational demands and scenarios.

In summary, the study not only formulates and validates a dynamic model for mobile platforms but also presents an effective system design, for mobile platforms equipped with Mecanum wheels. This work enhances the robotics field by providing a holistic methodology for analyzing and improving the dynamics and control of mobile robots.

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Modelarea dinamica in Simulink a unei platforme mobile autonoma cu locomotie mecanum considerând forțele de frecare

Acest articol oferă o descriere detaliată despre dezvoltarea și validarea unui model dinamic ale unui robot mobil utilizând Simulink-Simscape. Componenta fundamentală în dezvoltarea modelului este importul unui model CAD 3D din SolidWorks în Simulink-Simscape. Modelul dinamic al robotului mobil se bazează pe o locomoție cu roți Mecanum. Obiectivul principal al cercetării este monitorizarea consumului energetic pentru o conducere eficienta a platformei mobile. Studiul cuprinde o revizuire extensivă a modelelor dinamice existente, luând în considerare forțele de frecare, precum și proiectarea și modelarea cinematică a sistemelor de acționare pentru configurația de conducere omnidirecțională. Utilizând SolidWorks, a fost dezvoltată o reprezentare virtuală 3D a robotului și a fost integrată perfect în Simulink-Simscape pentru a construi modelul dinamic. Modelul matematic pentru cinematica și controlul robotului a fost formulat riguros în cadrul Simulink, utilizând matricea Jacobiană și transpusa sa pentru a descompune forțele rezistente la arborele motoarelor în componente inerțiale și de frecare, permițând simularea precisă a consumului de curent electric în timpul mișcării robotului. Articolul introduce, de asemenea, un diagramă caracteristică de bloc pentru evaluarea consumului de curent electric al motorului DC, necesara pentru analiza eficienței operaționala a robotului. Un aspect important al acestei cercetări constă în validarea experimentală a modelului dinamic prin măsurători în timp real ale curentului electric pe o platformă mobilă, confirmând acuratețea și practicitatea acestuia. Această abordare integrată a modelării dinamice și analiza forțelor de rezistență aduce o contribuție semnificativă în cadrul domeniului roboților mobili autonomi, oferind perspective valoroase pentru îmbunătățirea eficienței energetice și capacităților de conducere.

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