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DESIGN OF A CONTROL SYSTEM WITH A PREDICTIVE MODEL FOR A TWO-DRIVE MANIPULATOR WITH A PARALLEL STRUCTURE

Abstract. This work intends to contribute to the corpus of knowledge on parallel manipulators and their control by making the most use of Model Predictive Control. We aim to investigate par allel manipulator kinematics, dynamics, and control strategies in detail in order to open up op portunities for enhanced performance, flexibility, and precision in these robotic systems.
Key words: frame installation, manipulator, model predictive control, parallel structure, control system.

Introduction. Parallel manipulators have attracted a lot of interest and attention in the field of robotics and automation recently because of their distinctive qualities and possible uses. These manipulators, often referred to as parallel robots, differ from their serial counterparts in the way that their linkages and joints are set up, and as a result, they have advantages including increased rigidity, increased payload capacity, and higher precision [1]. Parallel manipulator design and control have become important research fields, fostering advancement in a variety of sectors including aerospace, industrial, medical robotics, and more.

Given in [1] their intricate kinematics and dynamics, parallel manipulators present a considerable challenge for effective control. Because of its proficiency in managing complex systems with nonlinearities, uncertainties, and restrictions, model predictive control (MPC), a sophisticated management approach, has become well-known. MPC is an intriguing option for the control of parallel manipulators because of its predictive character, which takes into account future system behaviour and enables real-time adaptation and optimization.

Analysis of recent research and publications. To set the stage for our exploration, we delve into the foundational concepts of parallel manipulator kinematics and dynamics, highlighting key design parameters and considerations. We then delve into the principles of Model Predictive Control, elucidating its strengths and

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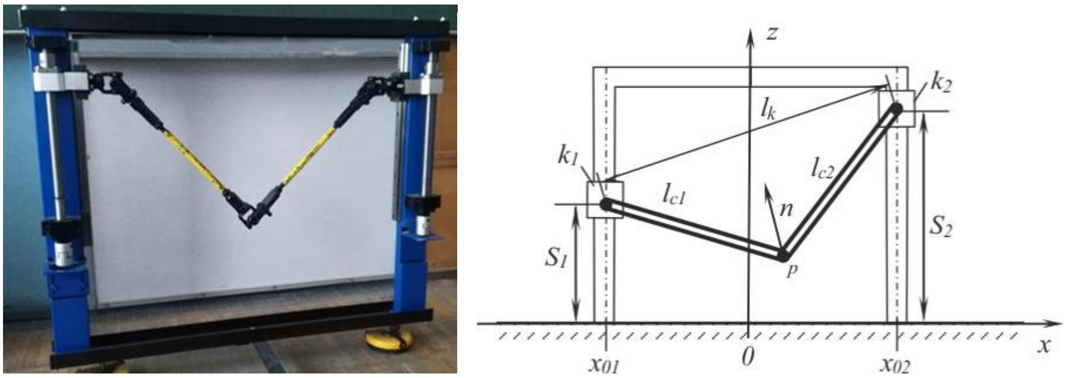
suitability for addressing the trajectory tracking in complexities inherent in the parallel manipulator system.

As we embark on this journey of investigating parallel manipulator model predictive control, it is imperative to acknowledge the pioneering work and significant contributions made by researchers in this interdisciplinary domain. By building upon the advancements made thus far and embracing the potential of MPC, we aim to further propel the field of parallel manipulators, opening new avenues for their utilization in various high-impact industries.

An example of such a frame installation of a parallel structure (fig. 1a) is a research stand with two guide rods which consist of a metal frame, which is equipped with two stepper motors, drives, hinges and a working body, which can be used as any technological tool such that paint head for varnishing, paints, cutting tools etc. [2].

In order to move the working tool (body) on the site, we need to move the carriages along the guide rods. This is ensured by the operation of drivers.

At Kinematic scheme of frame installation, is illustrated on fig. 1b [2], where $l_{c1}, l_{c2} = l$ - rod lengths, P the platform on which the working tool is installed, $d/2 = -x_{01} = x_{02}$ - distance between the supports, $S_{01} = 0$, $S_{02} = 0$ - initial positions of the carriages, k_1, k_2 - carriages.



a) Layout of the installation b) Kinematic scheme

Figure 1 – Two-drive manipulator with a parallel structure

A Kinematic Diagram is a powerful visual representation that elucidates the mechanical structure and motion characteristics of a manipulator. It conveys crucial insights into the relationships between different components and their roles in achieving controlled movement. In fig. 1 b we present a detailed Kinematic Diagram that illustrates the essential components and connections within the manipulator system. This diagram serves as a valuable tool for comprehending the manipulator's mechanical arrangement and its capabilities in achieving precise and controlled motion.

To initiate movement, we implement a controlled process that guides the actuator's motion from its initial point to a new position within the predefined working area.

The actuator's movement is characterized by a series of incremental steps, where it traverses a path from the initial point to its target position. This path is determined by the proposed trajectory, which may involve straight-line motion, curves, or even complex patterns based on the specific requirements of the task.

An example of moving the actuator within the working area [2] from the initial point with coordinates $(x_0, y_0) = (-0.1, -0.2)$ to the final point $(x_f, y_f) = (0.1, -0.15)$ along a straight line given as $y(t) = 0.25\,x(t) - 0.175$ is considered on fig. 2.

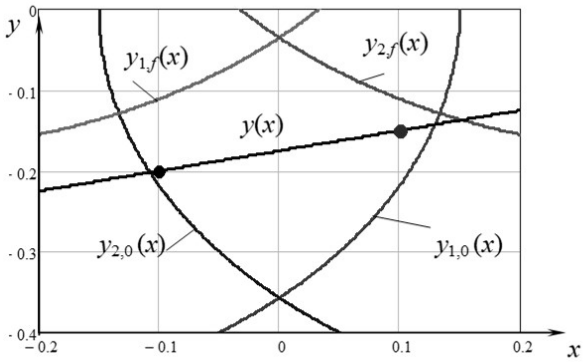
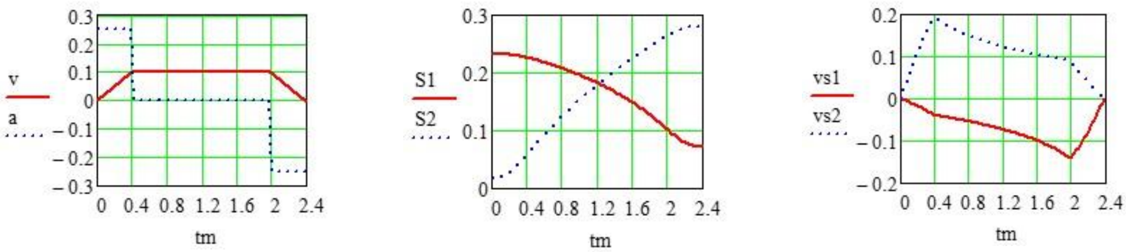


Figure 2 – Trajectory to track

In fig. 3 velocity and acceleration of the executive body, movement of carriages, and carriage velocities are shown respectively. These figures are modeling the behavior of the parallel manipulator in Ideal conditions for a given example.



a) Velocity and acceleration of the executive body b) Movement of carriages c) Carriage velocity

Figure 3 – Simulation results of the parallel manipulator behavior under ideal conditions

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To determine the mathematical model of this system, first studied its individual components. Two-phase hybrid stepper motors [3] are used to move the working body. The block diagram of the closed-loop control system of a hybrid stepper motor is presented in fig. 4.

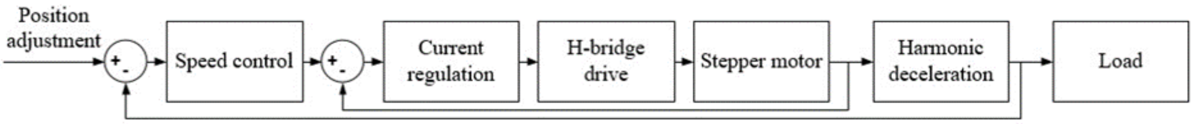

Figure 4 – Block diagram of the closed-loop control system

The inner circuit implements tracking of the winding current to a given current so that the hybrid stepper motor can smoothly output torque under the micro-step drive. The outer loop is a position loop, the goal is to track the output load at a given position. The transfer function of each stepper motor component is described in the block diagram shown on fig. 5.

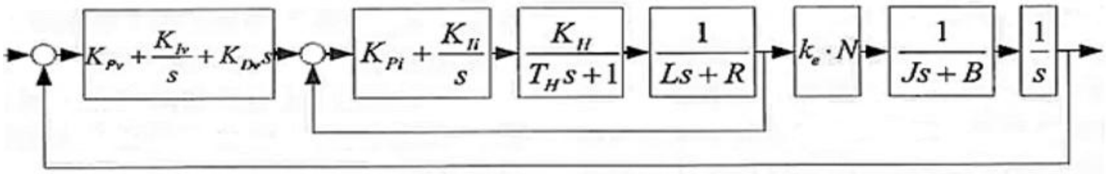

Figure 5 – Block diagram of the transfer function of a stepper motor system

The mechanical motion of the drivers refers to the physical movement and behavior of the mechanical components within the control system that are responsible for translating electrical signals into motion. These drivers play a critical role in controlling the movement of the load and managing the applied load torque. The mechanics of the motion involve the interaction between the stepper motor, load, and the mechanisms that facilitate controlled motion.

The mechanical motion of the drivers can be described as follows:

$$I\frac{d\omega}{dt} + B\omega = T_e - T_L, \tag{1}$$

$$T_L = f(x, y) \to \text{var}, \tag{2}$$

$$T_e = K_e i_q \text{ or } T_e = K_e N_2 i_q, \tag{3}$$

$$L\frac{di_q}{dt} + Ri_q = u, \tag{4}$$

$$T_H \frac{du}{dt} + u = K_H i_H \,, \tag{5}$$

$$K_{Ii} \int \Delta i \, dt + K_{Pi} \Delta i = i_H \,, \tag{6}$$

$$K_{D\theta} \frac{d\Delta\theta}{dt} + K_{P\theta} \Delta\theta = i_c \,. \tag{7}$$

Such that (1) and (2) describe the mechanical motion of the control system's load and the applied load torque, respectively. These equations quantify the relationship between the load's dynamics and the torque being exerted on it. Equations (3) and (4) model the torque applied to the stepper motor shaft and the electrical characteristics of the stepper motor, respectively. These equations establish the relationship between electrical signals and the resulting mechanical torque. Equations (5) illustrates the H-bridge drive, which is a circuit configuration commonly used to control the direction of current flow in a stepper motor. Equations (6) and (7) represent the PI (Proportional-Integral) current and PD (Proportional-Derivative) position regulators, respectively. These equations outline the control mechanisms that adjust the motor's current and position to achieve the desired motion. In equation (7) the integrated component is reduced in order to simplify the calculations.

The stepper motor orchestrates the coordinated motion of parallel actuators in the mechanical world, converting rotating power into linear motion via mechanical linkages. Parallel manipulators use complex equations, transformations, and optimization approaches to synchronize the movements of interconnected links and joints in the world of mathematics. The necessity to achieve harmonious motion in parallel configurations unites both domains while having different mechanisms and mathematical expressions, demonstrating the interplay between mechanical design and mathematical analysis. Therefore, a mathematical model of the system must be used to build a control system.

The aim of the research. This paper aims to explore the application of Model Predictive Control to parallel manipulator, focusing on its design, dynamics, and control strategies. By investigating the interplay between parallel manipulator mechanisms and advanced control techniques, we seek to enhance the performance, accuracy, and versatility of these robotic systems. The integration of MPC into parallel manipulator control offers the potential to address challenges related to trajectory tracking, obstacle avoidance, and efficient energy utilization.

Presentation of the main research material. Due to fig. 1b, the mathematical model that governs the movement of the carriages S_1 and S_2 based on the given

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coordinates (x, y) provides a systematic framework to understand and control the motion of the system [4]. This model encapsulates the essential principles that dictate how changes in the input coordinates translate to adjustments in the positions of the carriages.

The mathematical model elucidates the intricate relationship between the input coordinates (x, y) and the movement of the carriages S_1 and S_2. By establishing this connection, the model facilitates a deeper understanding of the system's behavior and serves as a foundation for effective control and optimization strategies.

$$x = \frac{1}{2} \cdot (S_2 - S_1) \cdot \sqrt{\frac{-(S_2 - S_1)^2 - 4 \cdot l^2 - d^2}{(S_2 - S_1)^2 + d^2}},$$
$$y = \frac{1}{2} \cdot \left(S_2 + S_1 - d \cdot \sqrt{\frac{-(S_2 - S_1)^2 + 4 \cdot l^2 - d^2}{(S_2 - S_1)^2 + d^2}} \right). \quad (8)$$

The subsequent transformation involves converting an angle, related to the orientation of the carriages, into the corresponding motion of the stepper motor. This transformation is a crucial step in translating desired angular adjustments into specific motor actions.

The transformation equation serves as a bridge between the abstract angular concept and the tangible motion of the stepper motor. This transformation allows for seamless integration of control commands, guiding the stepper motor to achieve the desired positions that correspond to the calculated carriage coordinates. Transformation of the angle to the motion of the stepper motor:

$$S_1 = \theta_1 N_1, \; S_2 = \theta_2 N_2. \quad (9)$$

The loading torque of a stepper motor is a critical parameter that influences the motor's performance and behavior. It refers to the twisting force exerted on the motor shaft when it is required to move or hold a load, overcoming various resistances and external forces. Understanding loading torque is essential for ensuring the stepper motor operates effectively and reliably in different applications.

Loading torque of the stepper motors is as follows:

$$S_1: \; T_{L1} = g_1(\theta_1, \theta_2), \quad (10)$$

$$S_2: \; T_{L2} = g_2(\theta_1, \theta_2). \quad (11)$$

Accurately estimating the loading torque is crucial for proper stepper motor selection and control. If the motor is subjected to insufficient torque, it may fail to move or hold the load effectively, leading to missed steps, instability, or stalling. On the other hand, providing excessive torque can result in excessive power consumption, motor overheating, or even damage to the motor or load.

Here, transforming the coordinates of a working point into the position of a stepper motor is a fundamental process in control systems and robotics. It involves converting abstract spatial coordinates into specific motor movements that drive the system to desired locations. This transformation bridges the gap between conceptual positions and actionable instructions for the stepper motor.

At its core, the transformation of coordinates into stepper motor position involves a multi-step procedure that harmonizes the geometric properties of the system with the mechanical characteristics of the motor. This process can be broken down into several key components:

$$\theta_{i,ref} = y_{ref} + \sqrt{l^2 - \left(x - x_{i,0}\right)^2} . \tag{12}$$

The control vector is multidimensional, with each element or component corresponding to a distinct aspect of motion control. For instance, in a system with a robotic arm, elements of the vector might dictate joint velocities, angles, or even end effectors forces. In the realm of autonomous vehicles, the control vector could encompass steering angles, accelerations, or braking forces. The richness of this vector lies in its ability to accommodate various degrees of freedom and dynamic attributes, rendering it a versatile tool for diverse applications.

Then, the control vector is described as:

$$\begin{gathered} u_1 = \theta_{1,ref}(t),\ u_2 = \frac{d\theta_{1,ref}(t)}{dt},\ u_3 = \frac{d^2\theta_{1,ref}(t)}{dt^2}, \\ u_4 = \theta_{2,ref}(t),\ u_5 = \frac{d\theta_{2,ref}(t)}{dt},\ u_6 = \frac{d^2\theta_{2,ref}(t)}{dt^2}. \end{gathered} \tag{13}$$

The control vector, denoted by $\vec{u}$, encompasses a diverse array of variables, each assuming a distinctive role in shaping the trajectory of the system. These elements are associated with specific purposes, contributing to the overall control strategy for the system.

Firstly, u_1 is responsible for controlling angles and directing the influence of $\theta_{1,ref}$ on the system's behavior. It plays a crucial role in determining the orientation of the system. Secondly, u_2 governs the slopes and captures the changes in $\theta_{1,ref}$ over time. Its control allows for adjustments to the rate of change of the angle. Thirdly, u_3 is dedicated to controlling the system's acceleration, and it closely moni-

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tors the second derivative of $\theta_{1,ref}$. By regulating acceleration, it manages the system's responsiveness to changes in $\theta_{1,ref}$.

Similarly, the control variables u_4, u_5 and u_6 take on analogous roles for $\theta_{2,ref}$. They are responsible for controlling the angles, velocities, and accelerations associated with $\theta_{2,ref}$, respectively.

The collective interplay of these control variables governs the system's trajectory, ensuring a coordinated and responsive behavior to achieve desired dynamic responses. The system's performance is guided by the carefully designed control strategy, ensuring efficient and effective control of the system's states and responses.

The vector of the states $\vec{q} = (q_1, q_2, q_3, q_4, q_5, q_6, q_7, q_8)^T$ represents a collection of state variables pertaining to the system under consideration. The individual components of $\vec{q}$ are defined as follows:

$q_1 = \theta_1$ ($q_5 = \theta_2$) corresponds to the first (second) angle in the system;

$q_2 = i_{driver\ 1}$ ($q_6 = i_{driver\ 2}$) denotes the first (second) driver current;

$q_3 = \frac{di_{driver\ 1}}{dt}$ ($q_7 = \frac{di_{driver\ 2}}{dt}$) represents the time derivative of the first (second) driver current, reflecting its rate of change;

$q_4 = \frac{d^2 i_{driver\ 1}}{dt^2}$ ($q_8 = \frac{d^2 i_{driver\ 2}}{dt^2}$) stands for the second derivative of the first (second) driver current, indicating its acceleration.

Together, these state variables $\vec{q}$ define the current state of the system and serve as crucial components in modelling and analyzing the system's dynamics and behaviour.

Finally, the mathematical model in space states is suggested as:

$$\dot{\vec{q}} = \mathbf{A}\vec{q} + \mathbf{f}(\vec{q}) + \mathbf{B}\vec{u}, \qquad \vec{y} = \mathbf{C}\vec{q}, \tag{14}$$

where we have

$$\mathbf{A} = \begin{pmatrix} a_{11} & a_{12} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & a_{55} & a_{56} & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & a_{85} & a_{86} & a_{87} & a_{88} \end{pmatrix},$$

where

$$a_{11}=\frac{-B}{I},\ a_{12}=\frac{K_e}{I},\ a_{55}=\frac{-B}{I},\ a_{56}=\frac{K_e}{I},$$

$$a_{41}=\frac{-K_{Ii}K_H B}{T_{Ii}LK_e},\ a_{42}=\frac{-K_{Ii}K_H I}{T_{Ii}LK_e},\ a_{43}=\frac{-R-K_{Pi}K_M}{T_{Ii}},\ a_{44}=-\frac{1}{T_{Ii}}-\frac{R}{L},$$

$$a_{85}=\frac{-K_{Ii}K_H B}{T_{Ii}LK_e},\ a_{86}=\frac{-K_{Ii}K_H I}{T_{Ii}LK_e},\ a_{87}=\frac{-R-K_{Pi}K_M}{T_{Ii}},\ a_{88}=-\frac{1}{T_{Ii}}-\frac{R}{L}.$$

Matrix **A** is structured to embody the interactions between specific state variables, showcasing the interconnectedness of the system's dynamics. Each a_{ij} element of the matrix **A** corresponds to the coefficient of the $j-$ th state variable in the differential equation governing the rate of change of the i-th state variable. In other words, a_{ij} represents how the j-th state variable influences the rate of change of the i-th state variable. a_{11} could represent how q_1 affects its own rate of change, a_{41} might indicate how q_1 influences the rate of change of q_4, and so on. Similarly, matrix **B** embodies the role of control inputs, highlighting their influence on steering the system's evolution.

$$\mathbf{B}=\begin{pmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ b_{41} & b_{42} & b_{43} & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & b_{84} & b_{85} & b_{86} \end{pmatrix},$$

where

$$b_{41}=\frac{K_{Ii}K_H K_{P\theta}}{T_{Ii}L},\ b_{42}=\frac{K_{Pi}K_H K_{P\theta}+K_{Ii}K_H K_{D\theta}}{T_{Ii}L},\ b_{43}=\frac{K_{Pi}K_H K_{D\theta}}{T_{Ii}L},$$

$$b_{84}=\frac{K_{Ii}K_H K_{P\theta}}{T_{Ii}L},\ b_{85}=\frac{K_{Pi}K_H K_{P\theta}+K_{Ii}K_H K_{D\theta}}{T_{Ii}L},\ b_{86}=\frac{K_{Pi}K_H K_{D\theta}}{T_{Ii}L}.$$

The vector $\mathbf{f}$ elegantly encapsulates nonlinear effects, showcasing their dependence on specific state variables.

$$\mathbf{f}=\begin{pmatrix} g_1(q_1,q_5) & 0 & 0 & f_1(q_1,q_5) & g_2(q_1,q_5) & 0 & 0 & f_2(q_1,q_5) \end{pmatrix}^T,$$

where

$$g_1(q_1,q_5)=-\frac{1}{I}T_{L1},\ g_2(q_1,q_5)=-\frac{1}{I}T_{L2},$$

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$$f_1(q_1,q_5) = -\frac{K_{Ii}K_H}{T_{Ii}LK_L}T_{L1}\,,\; f_2(q_1,q_5) = -\frac{K_{Ii}K_H}{T_{Ii}LK_L}T_{L2}\,.$$

Moreover, Matrix **C** is designed to extract pertinent information from the state vector, allowing for a focused understanding of the system's behavior through the observed outputs. It is obtained by

$$\mathbf{C} = \begin{pmatrix} 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 \end{pmatrix}.$$

Based on the state-space model, it becomes possible to design a model predictive control (MPC).

MPC is a sophisticated control strategy that anticipates future system behavior using a mathematical model and optimization techniques. In MPC design, a dynamic model of the system is created, and predictions are made for its future states based on different control inputs. The controller then optimizes a sequence of control actions over a defined prediction horizon to steer the system toward desired performance while accounting for constraints and disturbances. This predictive approach, coupled with real-time feedback, enables MPC to finely orchestrate complex processes and systems, ensuring optimal decision-making and responsive control in a wide range of applications across industries.

Suggested following MPC designing:

$$\min_{u_1 \ldots u_6} \int \left(\Delta\vec{q}^{\,T}\mathbf{Q}\Delta\vec{q} + \Delta\vec{u}^{\,T}\mathbf{R}\Delta\vec{u}\right)dt\,, \tag{15}$$

$$\begin{gathered} \text{subj. to } \dot{\vec{q}} = \mathbf{A}\vec{q} + \mathbf{f}(\vec{q}) + \mathbf{B}\vec{u}\,, \\ \vec{y} = \mathbf{C}\vec{q}\,, \end{gathered} \tag{16}$$

$$0 \le u_1, u_4 \le H\,,\; \left|u_2, u_5\right| \le V_{\max}\,,\; \left|u_3, u_6\right| \le a_{\max}\,, \tag{17}$$

$$0 \le q_1, q_5 \le H\,,\; q_2, q_6 \le i_{driver\ \max}\,. \tag{18}$$

The MPC model presented offers a powerful framework for steering dynamic systems along precise trajectories. The essence of this model lies in its ability to optimize control inputs, represented by $u_1,\ldots,u_6$, to minimize a performance cost over time. This cost, expertly expressed as a quadratic combination of state deviations $\Delta\vec{q}$ and control increments $\Delta\vec{u}$, underscores the strategy's focus on achieving both stability and efficiency.

The objective function is to minimize a quadratic cost over the time horizon. The cost function consists of two parts: a state cost **Q** (a positive semi-definite matrix that weighs the importance of different state variables) and a control input cost **R (**a positive definite matrix that weighs the importance of different control inputs**)**.

The model (16) embraces a set of dynamic constraints that encode the system's behavior. To ensure practicality, the model enforces a set of bounds (17)-(18) that reflect physical and operational limitations. The goal of the MPC is to minimize this cost function (15) with respect to the control input sequence $\vec{u}$.

The optimization problem is solved over a finite time horizon, where the state and control input trajectories are predicted for a certain future time period. Overall, MPC enables optimal decision-making and responsive control by leveraging predictive models and optimization techniques, making it applicable across a wide range of industries and applications. The mathematical model provides a rigorous framework for understanding and controlling the motion of parallel manipulators, laying the groundwork for further analysis and optimization.

Conclusion. In conclusion, the integration of Model Predictive Control (MPC) into parallel manipulator systems offers a promising avenue for advancing their control capabilities and performance across various applications. Through comprehensive exploration of the fundamental principles underlying parallel manipulators and the inherent power of MPC, the potential benefits of combining these technologies can be realized.

REFERENCES

1. Parallel Manipulators Applications. Modern Mechanical Engineering. 2012. URL: https://www.researchgate.net/publication/235456946_Parallel_Manipulators_Applications-A_Survey.

2. Nilova D. Analysis of the Kinematics Problems of a Two-Drive Mechanism with a Parallel Structure / D. Nilova, A. Rudakova, H. Rudakova. // Proceedings of the X All-Ukrainian Scientific and Practical Conference of Students, Postgraduates and Young Scientists on Automatic Control Dedicated to the Day of Astronautics. – 2023. – pp. 49–52.

3. Xu W. Derivantion of Transmission Function Model of Two-phase Hybrid Stepping Motor / W.Xu, J.Yan. // SPACE ELECTRONIC TECHNOLOGY. – 2011. – №3. – pp.50–53.

4. Neural Network Model for Laboratory Stand Control System Controller with Parallel Mechanisms / [V. Shymkovych, A. Rudakova, Y. Lebedenko et al.]. // Advances in Computer Science for Engineering and Education VI. ICCSEEA 2023. Lecture Notes on Data Engineering and Communications Technologies. Springer. – 2023. – № 181. – pp. 47-58.

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ISSN 2707-7977 (Online)

ЛІТЕРАТУРА

1. Parallel Manipulators Applications. Modern Mechanical Engineering. 2012. URL: https://www.researchgate.net/publication/235456946_Parallel_Manipulators_Applications-A_Survey.

2. Нілова Д.А. Аналіз задач кінематики двохприводного механізму з паралельною структурою. / Д.А. Нілова, А.А. Рудакова, Г.В. Рудакова // Матеріали Х Всеукраїнської науково-практичної конференції здобувачів вищої освіти та молодих вчених з автоматичного управління присвяченої Дню ракетно-космічної галузі України: Збірник наукових праць. – Херсон-Хмельницький: Вид-во ФОП Вишемирський В.С., 2023. - С. 49-52.

3. Xu W. Derivantion of Transmission Function Model of Two-phase Hybrid Stepping Motor / W.Xu, J.Yan. // SPACE ELECTRONIC TECHNOLOGY. – 2011. – №3. – pp.50–53.

4. Neural Network Model for Laboratory Stand Control System Controller with Parallel Mechanisms / [V. Shymkovych, A. Rudakova, Y. Lebedenko et al.]. // Advances in Computer Science for Engineering and Education VI. ICCSEEA 2023. Lecture Notes on Data Engineering and Communications Technologies. Springer. – 2023. – № 181. – pp. 47-58.

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Проектування системи керування з прогнозуючою моделлю для двоприводного маніпулятора паралельної структури

Ця стаття має на меті вивчити застосування моделі прогнозованого керування до паралельного маніпулятора, зосереджуючись на його конструкції, динаміці та стратегіях керування. Інтеграція MPC у паралельне керування маніпулятором дає потенціал для вирішення проблем, пов'язаних із відстеженням траєкторії, уникненням перешкод та ефективним використанням енергії. Математична модель забезпечує точну основу для розуміння та керування рухом паралельних маніпуляторів, закладаючи основу для подальшого аналізу та оптимізації. Завдяки всебічному дослідженню фундаментальних принципів, що лежать в основі паралельних маніпуляторів, і внутрішньої потужності MPC можна реалізувати потенційні переваги поєднання цих технологій.

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