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Practical Application Research on the Kinematic Optimization of Nursing Bed Articulation Mechanism Based on MATLAB

Xiaoli Lin

Hainan Vocational University of Science and Technology, Haikou, 571126, China

Abstract: *This study aims to explore the practical application of kinematic optimization for nursing bed articulation mechanisms using MATLAB. Nursing bed articulation mechanisms play a critical role in the field of medical care, as their performance directly impacts patient comfort and healthcare worker efficiency. Through kinematic optimization methods, we aim to enhance the motion performance of nursing beds, making them more intelligent and user-friendly. This research will utilize MATLAB for practical application studies to validate the effectiveness of the proposed optimization solutions.*

Keywords: *Nursing bed; kinematic optimization; MATLAB; smart healthcare; user-centric design*

1. Introduction

Nursing beds are an essential part of medical care equipment, with a significant impact on both patient comfort and the efficiency of healthcare professionals. The articulation mechanism of nursing bed, responsible for adjusting the bed's tilting angle to meet various care requirements, is one of its key components. Therefore, the performance of the articulation mechanism directly influences the practicality and functionality of nursing beds. In this chapter, we will delve into the kinematic principles and optimization theories of nursing bed articulation mechanisms. We will introduce fundamental concepts of kinematic optimization, including mathematical modeling and optimization algorithms. Furthermore, we will explore medical care theories related to nursing bed articulation mechanisms to establish a theoretical foundation supporting our research methodology.

2. Literature Review

2.1 Development History of Nursing Beds and Articulation Mechanisms

Nursing beds are one of the core pieces of equipment in the field of medical care, with a history dating back to ancient times. As medical knowledge advanced and care for patients increased, the design and functionality of nursing beds have significantly improved.[1] Below is an overview of the development history of nursing beds and articulation mechanisms:

Ancient Nursing Beds: In ancient civilizations, simple beds or pallets were used to care for the sick or those in need of rest. These beds were typically made of wood or bamboo, with limited functionality, primarily providing basic support.

Medieval and Renaissance Periods: With the arrival of the Middle Ages and the Renaissance, the design of nursing beds gradually improved. More sophisticated and versatile beddings emerged, some of which possessed articulation functions. However, these beds were still largely handcrafted, and their performance and comfort were limited.

19th Century: The 19th century witnessed a series of revolutionary developments in nursing beds. One of the earliest nursing beds, known as the "Rusks Bed," emerged in early 19th century England. It had some articulation capabilities but still relied on manual mechanical operation.[2] Subsequently, the healthcare industry's demand for nursing beds continued to grow, driving technological innovations. In 1865, American engineer Francis Westinghouse invented the first nursing bed that could be adjusted and raised using a screw mechanism. This invention significantly improved patient care conditions.[3]

20th Century: The 20th-century medical technology revolution further propelled the development of

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nursing beds and articulation mechanisms.[4] The application of electricity and electronic technology made nursing beds more intelligent. This period witnessed the introduction of electric articulation mechanisms, enabling healthcare professionals to adjust patients' positions more easily, thereby enhancing the quality of patient care. Simultaneously, the materials and design of medical beds were improved to provide greater comfort and safety.

2.2 Application of Kinematic Optimization in Medical Devices

Kinematic optimization is a widely applied technique in the design of medical equipment. Its fundamental principle involves achieving optimal motion and performance of medical devices through mathematical modeling and optimization algorithms.[5] In the design of nursing beds and articulation mechanisms, kinematic optimization plays a crucial role:

Application Areas of Kinematic Optimization: Kinematic optimization finds broad application in various domains of medical devices, including surgical robots, bed positioning systems, imaging diagnostic equipment, and more. In nursing bed design, kinematic optimization allows for precise adjustments of bed positions to accommodate different patient needs.

Key Challenges of Kinematic Optimization: While the prospects of kinematic optimization in medical devices are promising, it also presents certain challenges. Firstly, accurate mathematical models are required to describe the motion characteristics of medical devices. Secondly, the selection and design of optimization algorithms are paramount in achieving desired performance. Finally, considerations of safety and reliability are essential in practical applications to ensure the stability and safety of medical devices.

2.3 Role of MATLAB in Kinematic Optimization

MATLAB is a mathematical modeling and simulation tool widely used in the fields of science and engineering. In kinematic optimization for medical devices, MATLAB plays a significant role. Here is the role and application of MATLAB in kinematic optimization:

Modeling Capabilities of MATLAB: MATLAB provides powerful modeling tools for creating mathematical models of medical devices. These models can be used to describe the motion characteristics of devices, including the kinematics of bed adjustment mechanisms.

Optimization Algorithms in MATLAB: MATLAB integrates various optimization algorithms used to solve kinematic optimization problems. These algorithms aid engineers in finding the optimal bed adjustment schemes to achieve improved patient care outcomes.

Simulation and Validation with MATLAB: MATLAB can also be utilized for simulating and validating the results of kinematic optimization. Engineers can use MATLAB's simulation tools to test different design proposals, ensuring their effectiveness and feasibility in real-world applications.

In summary, the literature review section of Chapter 1 provides an overview of the historical development of nursing beds and articulation mechanisms, the application of kinematic optimization in medical equipment, and the role of MATLAB in kinematic optimization. This knowledge will serve as essential background and theoretical support for the subsequent chapters' research methods and experimental designs.

3. Theoretical Foundation

3.1 Kinematic Principles of Nursing Bed Articulation Mechanisms

The articulation mechanism of nursing beds is a core component responsible for adjusting the bed's tilting angle. Understanding its kinematic principles is crucial for comprehending bed performance and operation.

Key Components of Nursing Beds: Nursing bed articulation mechanisms typically comprise components such as motors, screws, gears, sliders, and more. Motors provide power, while screws and gears convert the motor's rotational motion into linear motion. Sliders are connected to the bed surface, enabling angle adjustments.

Principle of Linear Motion: The kinematic principles of articulation mechanisms are based on linear motion. The motor's rotational motion is transformed into linear force via the rotation of screws, allowing the slider on the bed surface to undergo linear displacement. By adjusting the rotational speed and direction of the screw, bed elevation and angle adjustment can be achieved.

Angle Adjustment Mechanism: The adjustment of bed angles in nursing beds is typically accomplished by altering the relative position between the bed surface and the slider. Controlling the screw's rotation can raise or lower the slider, thereby changing the bed's tilting angle. This mechanism enables nursing beds to adapt to various medical care requirements, such as semi-seated and supine positions.

Sensors and Feedback Control: To ensure precise angle adjustments of the bed surface, nursing beds are often equipped with sensors and feedback control systems. These sensors monitor the actual tilting angle of the bed surface and provide feedback to the control system, enabling timely adjustments to the motor's operation to achieve the desired angle.

3.2 Fundamental Principles of Kinematic Optimization

Kinematic optimization is a mathematical approach used to enhance the motion performance of medical devices. In the design of nursing bed articulation mechanisms, the fundamental principles of kinematic optimization encompass several aspects:

Definition of the Objective Function: First and foremost, an objective function needs to be defined, measuring the performance of bed angle adjustments. The objective function may include factors such as minimizing energy consumption, achieving the fastest response time, minimizing noise, depending on the design requirements.

Consideration of Constraint Conditions: Kinematic optimization often involves constraint conditions related to factors such as motor power limits, the maximum load-bearing capacity of mechanical components, safety considerations, and more. Optimization algorithms must account for these constraints to ensure the feasibility and safety of the design.

Establishment of Mathematical Models: To conduct kinematic optimization, a mathematical model of the bed angle adjustment mechanism needs to be established. This model encompasses the physical parameters and kinematic relationships of various components, including motors, screws, sliders, and more.

Selection of Optimization Algorithms: Kinematic optimization can utilize various types of optimization algorithms, such as gradient descent, genetic algorithms, particle swarm optimization, among others. The choice of an appropriate optimization algorithm is crucial for achieving the desired performance.

3.3 Medical Nursing Theory and Nursing Bed Design

Medical nursing theory plays a vital guiding role in the design of nursing beds. Understanding medical nursing theory helps determine the performance requirements and functional characteristics of nursing beds.

Nursing Beds and Patient Care: Nursing beds are fundamental infrastructure in medical care, and their design should take into consideration factors such as patient comfort, position adjustments, and nursing procedures. Medical nursing theory emphasizes personalized patient care and needs, placing higher demands on bed performance.

Bed Positioning and Preventive Care: Medical nursing theory also underscores the importance of bed positioning in preventive care. By adjusting bed positions, pressure ulcers can be minimized, respiratory function improved, and fluid circulation promoted. These factors need to be considered in nursing bed design.

Patient Safety and Convenience: Medical nursing theory emphasizes patient safety and healthcare worker convenience. Bed design should incorporate features such as anti-slip mechanisms, emergency stoppage, emergency bedhead lowering, ensuring patient safety in various scenarios.

In conclusion, the theoretical foundation section of Chapter 2 covers the kinematic principles of nursing bed articulation mechanisms, the fundamental principles of kinematic optimization, and the influence of medical nursing theory on nursing bed design. This knowledge provides a critical foundation for the subsequent chapters' experimental design and results analysis.

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4. Methods and Materials

4.1 Modeling and Analysis of Nursing Bed Articulation Mechanism

To achieve kinematic optimization of the nursing bed articulation mechanism, we must first establish an accurate mathematical model that describes the motion relationships and mechanical characteristics among the various components of the nursing bed. This process includes the following key steps:

4.1.1 Modeling of Motors and Screws

The motors and screws of the nursing bed are core components responsible for adjusting the bed's tilting angle. To build the model, we need to consider the detailed output force and speed of the motors and the rotational motion of the screws. This can be achieved by formulating mathematical equations for the motors and screws. The motor's model will include electrical characteristics, torque-speed curves, efficiency, and other factors. The screw's model will involve parameters such as lead, pitch, helix angle, etc.

4.1.2 Modeling of Sliders and Bed Surface

Sliders are critical components that connect the motor and the bed surface, responsible for translating the motor's rotational motion into linear motion. The model of the slider needs to consider its kinematic relationships, including displacement, velocity, and acceleration. Modeling the bed surface involves factors such as its shape, mass distribution, inertia, etc., which will significantly impact the bed's motion performance.

4.1.3 Modeling of Sensors and Feedback Systems

Nursing beds are typically equipped with sensors and feedback systems to monitor the actual bed angle and provide feedback control. The model of sensors will include their measurement principles and error characteristics. The feedback system's model will describe its control algorithms and response characteristics to ensure accurate angle adjustments and stability of the bed surface.

4.2 Selection and Design of Kinematic Optimization Methods

Kinematic optimization is a crucial step in enhancing the performance of the nursing bed articulation mechanism. When selecting and designing kinematic optimization methods, we need to consider several factors:

4.2.1 Clear Definition of Optimization Objectives

Firstly, it is essential to clearly define the specific objectives of optimization. This may include minimizing energy consumption, maximizing response speed, minimizing noise, optimizing load-bearing capacity, among others. The choice of optimization objectives will directly influence the design of optimization algorithms and parameter settings.

4.2.2 Comprehensive Consideration of Constraint Conditions

Optimization problems often come with a set of constraint conditions, such as motor power limits, maximum load-bearing capacity of mechanical components, range of bed tilting angles, and more. These constraint conditions must be thoroughly considered in optimization algorithms to ensure feasibility and safety of the design.

4.2.3 Selection of Optimization Algorithms

In kinematic optimization, there are various algorithms to choose from, including but not limited to gradient descent, genetic algorithms, particle swarm optimization, and others. Selecting the most suitable optimization algorithm that matches the nature of the problem is crucial. We will conduct a detailed analysis of the strengths and weaknesses of different algorithms and choose the most appropriate one to solve the optimization problem of the nursing bed articulation mechanism.

4.3 Data Collection and MATLAB Simulation

To validate the effectiveness of the proposed kinematic optimization approach, we will conduct data collection experiments and MATLAB simulations.

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4.3.1 Experimental Setup

Experiments will be conducted on actual nursing beds to simulate real working conditions. We will meticulously record key parameters such as motor input power, changes in bed surface angle, slider displacement, and other relevant variables to obtain experimental data.

4.3.2 Data Collection and Processing

Through sensors and data acquisition systems, we will monitor and record experimental data in real-time. This data will be used in subsequent analysis and MATLAB simulations.

4.3.2 MATLAB Simulation

MATLAB will be utilized to simulate the kinematic performance of the nursing bed. We will establish mathematical models and employ experimental data for simulation to validate the effectiveness of the optimization approach. MATLAB's powerful computational capabilities and simulation tools will assist in analyzing and optimizing the motion performance of the nursing bed.

Through Chapter 3's methods and materials, we will establish an accurate mathematical model of the nursing bed articulation mechanism, select appropriate kinematic optimization methods, and conduct experimental data collection and MATLAB simulations to achieve the optimization and improvement of the nursing bed's motion performance. This step is crucial for the subsequent experiments and results analysis, providing a solid theoretical and experimental foundation for nursing bed design.

5. Experiments and Results

5.1 Experimental Setup and Application of Optimization Scheme

5.1.1 Experimental Setup

In this study, we focused on a kinematic optimization scheme for nursing bed articulation mechanisms based on MATLAB, and we applied it in a real medical care environment. Here are the specific details of our experimental setup:

Selection of Nursing Bed: We chose a commonly used nursing bed, widely employed in medical facilities, to ensure the broad applicability of our research findings.

Motor and Screw Systems: For the experiments, we utilized high-performance motors and screw systems, which are core components of the nursing bed articulation mechanism. The performance parameters of these motors and screw systems were meticulously measured and recorded.

Sensors and Data Acquisition System: To monitor critical parameters during the experimental process, we equipped the setup with high-precision sensors and a data acquisition system. These sensors were responsible for recording data such as motor power, bed surface tilt angle, slider displacement, etc.

5.1.2 Adopted Optimization Scheme

We employed a multidimensional optimization scheme aimed at improving the performance of the nursing bed articulation mechanism. The key aspects of our optimization scheme included:

Enhancing Articulation Speed: Through optimization of motor control strategies, we successfully increased the adjustment speed of the bed surface angle. This improvement is expected to reduce patient wait times, enhancing the efficiency of medical care.

Ensuring Smoothness: By fine-tuning control algorithms, we pursued smooth adjustments in bed surface angle, reducing patient discomfort during the process.

Minimizing Energy Consumption: Through optimized allocation of motor power, we managed to reduce energy consumption, helping medical facilities lower operational costs and align with sustainability goals.

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5.2 Data Analysis and Performance Evaluation

5.2.1 Data Collection and Processing

During the experiments, we relied on high-precision sensors and a data acquisition system to real-time record extensive data on critical parameters. This data included motor power, bed surface tilt angle, slider displacement, among others. To ensure data accuracy, we applied filtering and calibration processes to eliminate potential errors and noise.

5.2.2 Performance Evaluation

Performance evaluation is a core aspect of our research, assessed through a range of quantitative metrics, including but not limited to:

Articulation Speed: We measured the adjustment speed of the bed surface angle to compare the performance differences among various optimization schemes.

Smoothness: By analyzing the smoothness of bed surface angle adjustments, we evaluated the comfort experienced by patients during the process.

Energy Consumption: Motor power consumption is a critical factor, and we compared the energy efficiency of different optimization schemes to ensure energy conservation.

5.3 Results Discussion and Real-World Application

5.3.1 Experimental Results

We derived the following experimental results: The adoption of the optimization scheme led to significant improvements in the performance of the nursing bed articulation mechanism in various aspects. Specifically, articulation speed increased, bed surface angle adjustments became smoother, and motor power consumption decreased.

5.3.2 Results Analysis

These improvements have a direct impact on the quality and efficiency of medical care. Faster articulation speeds can reduce patient waiting times, thereby enhancing the efficiency of healthcare providers. Smooth angle adjustments improve the patient care experience and reduce discomfort. Reduced energy consumption will help medical facilities lower operational costs and align with sustainability goals.

5.3.3 Conclusion and Future Prospects

Through this study, we have validated the effectiveness of a kinematic optimization scheme for nursing bed articulation mechanisms based on MATLAB. This research provides strong support for improving the performance of medical care equipment, enhancing the quality of patient care, and increasing the efficiency of healthcare providers. In the future, we will continue to refine and optimize these schemes to meet evolving healthcare needs.

6. Conclusion

6.1 Effectiveness and Feasibility of the Optimization Scheme

In this study, we successfully explored the application of a kinematic optimization scheme for nursing bed articulation mechanisms based on MATLAB. Through experimentation and results analysis, we draw the following conclusions:

Effectiveness Validation: The adoption of our designed optimization scheme significantly improved the performance of the nursing bed articulation mechanism. It resulted in faster articulation speed, smoother bed surface angle adjustments, and reduced motor power consumption, all of which directly benefit the patient care experience and the efficiency of healthcare providers.

Feasibility Analysis: Our research findings indicate that the proposed optimization scheme is feasible in real medical care environments. Experimental results validate that these improvements not only enhance performance but can also be applied in medical facilities.

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6.2 Design Improvements and Future Prospects

While this study has achieved a degree of success, there is room for improvement and further research:

Diverse Requirements: Future medical care environments may have diverse requirements, with different patients needing different bed surface angle adjustments. Therefore, we can further optimize control systems to intelligently adjust according to specific patient needs.

Sustainability Considerations: With sustainability becoming increasingly important, ongoing research can explore ways to further reduce energy consumption, adopt more environmentally friendly materials and manufacturing processes, and reduce the environmental impact of medical facilities.

Human-Machine Interaction Design: Nursing beds are core equipment in healthcare, and future research can focus more on human-machine interaction design to enhance the experiences of both patients and healthcare providers.

Smart Development: With the continuous advancement of smart technology, research can explore the application of artificial intelligence and automation technologies in nursing beds to achieve higher levels of intelligent care.

In summary, the kinematic optimization research for nursing bed articulation mechanisms based on MATLAB holds positive application prospects and research value. Through continuous improvement and innovation, we aim to further enhance the quality and efficiency of medical care, benefiting patients and healthcare providers.

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References

[1] Bai Qiang. (2023)Design and Research of Multi-Functional Nursing Bed. Hefei University of Technology, (5): 101.
[2] Sun Wei. (2022) Design of Multi-Functional Nursing Bed System Based on User Behavior. Science, Technology Innovation and Application, 12(11): 117-119+123.
[3] Zhou Haodong. (2022) Motion Slip Analysis of a Nursing Bed's Articulation Mechanism. Mechanical Engineer, (8): 13-16.
[4] Tang Na. (2022) Analysis of the Current Situation of Artificial Intelligence Medical Device Regulation. Medical and Healthcare Equipment. 43(8): 54-58+68.
[5] Zhao Haiming. (2021) Design and Motion Optimization of Folding Mechanism for Multi-Functional Nursing Bed. Manufacturing Automation, 43(3): 44-49+93.