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Design and Development of a Smart Transfer Bed

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Abstract

Patient handling and transfer activities in hospitals are physically demanding tasks that frequently expose healthcare workers to musculoskeletal disorders (MSDs), particularly back injuries. Conventional patient transfer methods require multiple nurses and become increasingly difficult when handling overweight or paralyzed patients. This paper presents the design and development of a Smart Transfer Bed intended to reduce manual effort and improve patient safety during transfers between hospital beds, diagnostic equipment, and wards. The proposed system integrates a linear actuator-driven sliding platform with ball transfer units to achieve smooth and controlled patient movement. The frame structure is fabricated using lightweight aluminum profiles to ensure durability and portability. The developed prototype is capable of supporting patients weighing up to 150 kg. Initial testing revealed alignment and motion instability issues, which were corrected through structural modifications and guide rail adjustments. Experimental results demonstrate that the smart transfer bed provides smooth linear motion, minimizes transfer time, and significantly reduces caregiver physical strain. The proposed system offers a cost-effective and ergonomic solution for modern healthcare facilities.

Introduction

Patient transfer is one of the most common activities performed in hospitals and healthcare centers. Nurses and caregivers frequently move patients from hospital beds to wheelchairs, examination tables, MRI beds, or X-ray platforms. These tasks are physically demanding, especially when dealing with elderly, overweight, or paralyzed patients. Improper manual handling often results in musculoskeletal disorders (MSDs), chronic back pain, and workplace injuries among healthcare workers.

According to healthcare safety studies, patient handling contributes significantly to occupational injuries among nurses. Traditional transfer methods usually require two or more caregivers to safely reposition a patient. However, due to staff shortages and increasing patient numbers, hospitals require automated systems capable of reducing human effort while maintaining patient comfort and safety.

This research focuses on the design and implementation of a Smart Transfer Bed that automates the patient transfer process using a smooth-motion mechanism. The proposed system uses a linear actuator to move a sliding platform while ball transfer units reduce friction and support multidirectional movement. The developed system is intended to improve

hospital ergonomics, reduce injury risk, and enhance patient care quality.

Objectives

The objectives of this research are:

1. To design a smart transfer bed capable of safely transferring patients between surfaces.
2. To minimize physical strain and injury risks for nurses and caregivers.
3. To provide smooth and stable patient movement using an automated mechanism.
4. To develop a lightweight and durable structure capable of supporting up to 150 kg.
5. To evaluate the performance and safety of the developed prototype.

Literature Review

Patient transfer technologies have evolved significantly in recent years due to increasing demand for healthcare automation. Conventional transfer techniques mainly rely on manual lifting, sliding sheets, or hydraulic systems. Although these approaches reduce some effort, they still require considerable human involvement.

Automated transfer systems using conveyor belts, robotic arms, and pneumatic mechanisms have been proposed in previous studies. Conveyor-based systems provide continuous motion but are often bulky and expensive. Robotic transfer systems offer high precision but require advanced control systems and maintenance. Pneumatic systems provide smooth movement but may suffer from air leakage and limited load stability.

Linear actuator systems have gained popularity because of their simplicity, reliability, and controlled motion characteristics. Similarly, ball transfer units are widely used in industrial material handling applications to reduce friction and enable multidirectional movement. Combining these technologies can provide an effective solution for hospital patient transfer systems.

Despite existing developments, many commercial systems remain costly and inaccessible for small hospitals. Therefore, there is a need for a cost-effective, lightweight, and user-friendly transfer bed.

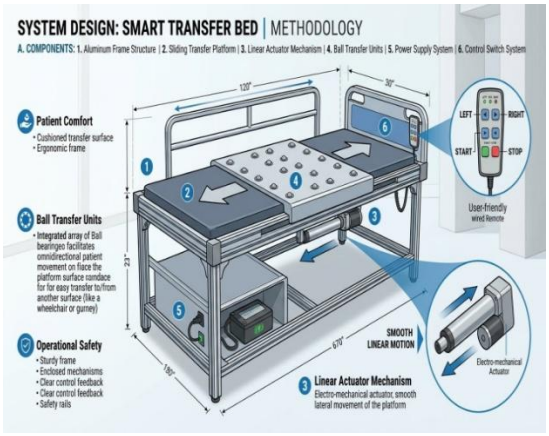
Methodology

1. System Design

The Smart Transfer Bed consists of the following major components:

- Aluminum frame structure
- Sliding transfer platform
- Linear actuator mechanism
- Ball transfer units
- Power supply system
- Control switch system

The overall design aims to achieve smooth linear motion while maintaining patient comfort and operational safety.



2. Mechanical Structure

The frame is constructed using aluminum profiles because of their lightweight nature, corrosion resistance, and structural strength. The sliding platform is mounted on ball transfer units that reduce friction and facilitate smooth movement.

The maximum load capacity of the system is 150 kg. Structural analysis was considered during the design process to ensure stability under loading conditions.

3. Linear Actuator Mechanism

The patient transfer platform is driven using a linear actuator. The actuator converts rotational motor motion into linear displacement, enabling controlled pushing and pulling actions.

The actuator motion can be represented by:

$v=t/d$

where:

v = linear velocity

d = displacement

t = transfer time

The actuator was selected based on load capacity, stroke length, and operating speed.

4. Ball Transfer Mechanism

Ball transfer units are installed beneath the sliding platform to minimize friction and ensure smooth motion during patient transfer. The load distribution can be expressed as:

$F=\mu N$

where:

F = frictional force

μ = coefficient of friction

N = normal force

The use of ball transfer units significantly reduces frictional resistance and improves motion efficiency.

Implementation

1. Prototype Fabrication

The prototype was fabricated using modular aluminum profiles connected through fastening brackets. The sliding platform was mounted on multiple ball transfer units arranged uniformly to distribute patient weight evenly.

A DC-powered linear actuator was installed beneath the platform and connected to a control switch for forward and reverse movement.

2. Assembly Process

During assembly, several issues were encountered related to platform alignment and uneven motion. The sliding platform initially deviated from its linear path due to improper guide positioning.

To solve this issue:

1. Additional guide supports were installed.
2. Ball transfer alignment was corrected.
3. Structural balancing modifications were performed.

After modification, the platform achieved smooth and stable motion.

3. Control System

The control system uses a simple switch-based mechanism to operate the linear actuator. The operator can initiate forward and reverse movement using push-button controls.

Safety measures include:

- Emergency stop switch
- Speed limitation
- Stable frame locking mechanism

Results And Discussion

The developed Smart Transfer Bed was tested under different loading conditions. Experimental evaluation focused on motion smoothness, load capacity, transfer speed, and operational safety.

1. Load Testing

The system successfully supported loads up to 150 kg without structural deformation or instability.

2. Motion Analysis

The sliding platform moved smoothly after guide modifications. Ball transfer units effectively reduced friction and enabled stable motion.

3. Ergonomic Benefits

The system reduced the physical effort required by caregivers during patient transfer. Only one operator was needed to perform the transfer safely.

4. Safety Performance

No sudden jerks or instability were observed during testing. The transfer motion remained controlled and comfortable for the patient.

Advantages Of the Proposed System

1. Reduces nurse workload and physical strain
2. Minimizes risk of musculoskeletal injuries
3. Provides smooth and safe patient transfer
4. Lightweight and portable structure
5. Cost-effective compared to robotic systems
6. Easy operation and maintenance

Limitations

1. Requires electrical power supply
2. Limited portability on uneven surfaces
3. Manual alignment with adjacent beds is necessary
4. Prototype requires further optimization for commercial deployment

Future Work

Future improvements may include:

1. Integration of sensors for automatic alignment
2. Wireless remote-control operation
3. IoT-based patient monitoring system

4. Battery backup for emergency operation
5. AI-assisted positioning mechanism

Conclusion

This research presented the design and development of a Smart Transfer Bed intended to improve patient handling in hospitals. The proposed system successfully reduced manual effort and provided smooth patient transfer using a linear actuator and ball transfer mechanism. The lightweight aluminum frame ensured structural stability while supporting loads up to 150 kg.

Experimental testing confirmed that the developed prototype improved motion smoothness, reduced caregiver workload, and enhanced patient safety. The proposed system represents a practical and economical solution for healthcare facilities seeking ergonomic patient transfer technologies.

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