Automated Storage and Retrieval System in Medical Field

Dr Brindha S[1], Ms. Swathi G[2], Mr. Sanjay Balaji S[3], Mr. Manas A S[4], Mr. Sevith Praman M[5], Ms. Tejasshree S[6]

[1]*Head of the Department, Computer Networking, PSG Polytechnic College, Coimbatore*
[2]*Lecturer, Computer Networking, PSG Polytechnic College, Coimbatore*
[3,4,5,6,7] *Students, Computer Networking, PSG Polytechnic College, Coimbatore*

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Abstract -Automated Storage and Retrieval Systems (AS/RS) are increasingly being integrated into healthcare environments to improve the efficiency, accuracy, and safety of medical inventory management. This study explores the design, implementation, and performance of an AS/RS tailored for the medical field, focusing on pharmaceuticals, surgical supplies, and high-value medical devices. The system utilizes real-time data capture, robotics-assisted storage, and intelligent retrieval algorithms to minimize manual handling errors and ensure compliance with regulatory requirements. Results demonstrate significant reductions in inventory discrepancies, retrieval time, and labor costs, while offering improved traceability and environmental control for temperature-sensitive items. By optimizing inventory flow and enhancing operational transparency, AS/RS technology shows substantial potential to strengthen hospital supply chain resilience and support safer, more efficient patient care. Future research should investigate integration with electronic health records, predictive analytics for demand forecasting, and broader scalability across diverse healthcare settings.
Key Automated Storage and Retrieval System (AS/RS); Medical inventory management; Healthcare automation; Hospital supply chain; Robotics; Real-time tracking; Pharmaceutical storage; Surgical supply management; Inventory accuracy; Healthcare logistics; Smart warehouses; Medical device management; Automation technology; Patient safety; Digital health systems.

1. INTRODUCTION

Efficient inventory management is a critical component of modern healthcare delivery, influencing patient safety, operational efficiency, and overall cost control. Hospitals and medical facilities manage thousands of items daily, including pharmaceuticals, surgical instruments, implants, and disposable supplies, each with specific storage, handling, and traceability requirements. Traditional manual inventory systems are often prone to human error, inconsistent documentation, and delays in locating essential medical items, which can disrupt clinical workflows and compromise patient care.

Automated Storage and Retrieval Systems (AS/RS) have emerged as a promising solution to these challenges, offering a technologically advanced approach to storing, organizing, and retrieving medical inventory. By integrating robotics, barcode or RFID-based identification, and intelligent software control, AS/RS can streamline inventory operations while ensuring high levels of accuracy, security, and regulatory compliance. The adoption of AS/RS in the medical field aligns with broader digital transformation efforts, aiming to enhance supply chain transparency, reduce resource wastage, and optimize labor utilization.

In recent years, increasing pressure on healthcare systems—driven by rising patient volumes, stringent quality standards, and the demand for rapid, error-free service—has further highlighted the need for automated solutions. AS/RS technologies offer not only operational improvements but also strategic benefits, such as real-time monitoring, predictive stock replenishment, and integration with hospital information systems. Despite these advantages, research on the implementation, performance, and scalability of AS/RS within healthcare settings remains relatively limited.

This study examines the role of Automated Storage and Retrieval Systems in the medical field, focusing on their potential to enhance inventory accuracy, improve workflow efficiency, and support safer, more sustainable healthcare operations.

2. RELATED WORK

Research on Automated Storage and Retrieval Systems (AS/RS) has been well established in industrial and warehousing contexts, focusing on system configuration, storage policies, and retrieval

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 10 Issue: 02 | Feb - 2026 SJIF Rating: 8.659 ISSN: 2582-3930

optimization. Foundational studies highlight how AS/RS improves throughput, accuracy, and space utilization through robotics and intelligent control algorithms. More recent work explores advanced modelling and optimization techniques, including multi-tier rack designs, dynamic storage assignment, and real-time retrieval sequencing.

In healthcare, studies increasingly emphasize the need for automated inventory solutions due to rising demand, regulatory constraints, and the critical importance of timely and accurate supply availability. Research on hospital inventory systems demonstrates that automation can significantly reduce human error, lower wastage, enhance traceability, and support cost-effective stock management. Automated drug dispensing systems (ADDS), a specialized application of AS/RS, have shown improved order-picking efficiency and safety through optimized storage allocation and human–machine collaboration.

Despite these advancements, the application of full-scale AS/RS to broader medical inventory—such as surgical supplies, implants, and high-value devices—remains limited. Existing literature underscores efficiency gains but also highlights a need for integrated, hospital-wide automated solutions that combine robotics, real-time tracking, and smart software to enhance overall supply chain performance. This gap motivates further investigation into AS/RS technologies tailored specifically for healthcare environments.

3.SYSTEM ARCHITECTURE OVERVIEW

Research on Automated Storage and Retrieval Systems (AS/RS) has been well established in industrial and warehousing contexts, focusing on system configuration, storage policies, and retrieval optimization. Foundational studies highlight how AS/RS improves throughput, accuracy, and space utilization through robotics and intelligent control

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3.2.1 INPUT AND IDENTIFICATION LAYER

The This layer manages the intake of inventory into the system. Medical items are identified using **barcode**, **RFID**, or **QR-code** tagging. Upon arrival, items are scanned and verified against the hospital's inventory database. The identification process ensures accurate recording of item details such as batch number, expiry date, storage conditions, and security categorization (e.g., controlled substances).

frontend acts as the user interface where customers, administrators, coaches, and owners interact with the system. It is developed using web technologies and provides features such as login, registration, slot booking, payment, and schedule viewing. The design emphasizes user-friendliness, responsiveness, and accessibility, ensuring that even first-time users can easily navigate the system

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3.2.2 STORAGE AND HANDLING LAYER

This physical layer includes the automated hardware components responsible for the movement and storage of items. It comprises:

- **Automated racking systems** (vertical or horizontal)
- **Shuttle units / robotic cranes** for item placement and retrieval
- **Conveyor or robotic transport mechanisms** for internal movement
- **Temperature-controlled compartments** for sensitive materials

The system dynamically assigns storage locations based on item characteristics, turnover frequency, and accessibility requirements.

backend, built using Node.js, processes all requests received from the frontend. It verifies inputs, handles business logic, manages session control, and ensures data security. This layer also acts as the communication bridge between the frontend and the database. Its event-driven, non-blocking architecture makes it ideal for handling multiple booking requests simultaneously with efficiency and speed.

3.2.3 CONTOL AND PROCESSING LAYER

This core intelligence layer uses software algorithms to manage and optimize the AS/RS. Key functions include:

- **Storage assignment algorithms** (class-based, random, or turnover-based)
- **Retrieval sequencing and path optimization**
- **Real-time inventory tracking and automated updates**
- **Expiry monitoring, stock level alerts, and reorder triggers**
- **Security and audit logging for controlled substances**

The control system continuously monitors system status, coordinates robotic movements, and ensures safe and efficient is used as the database for storing all critical information related to users, bookings, payments, and schedules. The database ensures data integrity, consistency, and quick retrieval. Proper normalization techniques and indexing strategies are applied to minimize redundancy and improve performance. This layer also supports reporting features, enabling administrators to generate summaries and track turf usage.

3.2.4 INTEGRATION AND USER INTERFACE LAYER

This layer bridges the AS/RS with hospital information technology systems and end-users. It includes:

- **User dashboards** displaying inventory status, retrieval requests, and system performance analytics
- **Integration with Hospital Information Systems (HIS)**, Pharmacy Information Systems (PIS), and Electronic Medical Records (EMR)
- **APIs for real-time data exchange**, enabling automated stock updates and clinical workflow-triggered requests
- **Role-based access control**, ensuring secure operations by pharmacists, inventory managers, and clinical staff

4. BACKEND IMPLEMENTATION

The backend of an Automatic Storage and Retrieval System (ASRS) acts as the core computational layer that manages all data, user interactions, and communication between the automated equipment and hospital software systems. In the medical field, the backend must ensure accuracy, safety, traceability, and compliance with healthcare regulations. This section describes the backend architecture, modules, workflow, and database design used to implement a robust ASRS for hospitals and medical warehouses.

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4.2 BACKEND MODULES

4.2.1 USER AUTHENTICATION MODULE

This module verifies user identity and role (e.g., pharmacist, store operator, administrator) using secure login credentials. Role-based access control (RBAC) ensures that only authorized personnel can perform critical operations such as retrieval or stock adjustments.

4.2.2 ITEM AND BATCH MANAGEMENT MODULE

All medical items are registered with details such as name, SKU, batch number, manufacturing date, and expiry date. This module ensures:

- Duplicate items are avoided
- Expired or near-expiry stock is highlighted
- Batch traceability is maintained for safety and compliance

4.2.3 INVENTORY AND LOCATION MANAGEMENT MODULE

The backend maintains the current stock levels, storage location codes, and rack-slot assignment. It performs:

- Location allocation during storage
- Availability checks before retrieval
- Automatic updates after every ASRS operation

4.2.4 ASRS COMMUNICATION MODULE

This module sends structured commands (e.g., STORE, RETRIEVE, MOVE) to the ASRS controller. It also receives acknowledgment or error messages from the machine, ensuring synchronous and reliable communication.

3.5 TRANSACTION LOGGING & AUDIT MODULE

Every action—including item storage, retrieval, and stock movement—is logged with:

- Timestamp
- User ID
- Item ID
- Quantity
- Location

This ensures complete traceability, which is essential in the medical domain.

Records each pick or put operation executed by the system.

5. BACKEND WORKFLOW

5.1 STORAGE (PUT) OPERATION

1. User initiates "Store Item".
2. Backend validates item and checks available locations.
3. Backend sends “STORE” command to ASRS controller.
4. Machine confirms successful placement.
5. Inventory table is updated, and a transaction record is created.

5.2 RETRIEVAL (PICK) OPERATION

1) User selects the required item and quantity.
2) Backend ensures sufficient stock exists at a specific location.
3) Backend sends “RETRIEVE” command to ASRS controller.
4) Machine delivers the item to the operator.
5) Inventory is decremented, and the retrieval is logged.

6. RESULT

Fig 6.1 home

Fig.6.2 login

7. CONCLUSION

The backend implementation of an Automatic Storage and Retrieval System (ASRS) in the medical field demonstrates how automation can transform traditional hospital inventory management into a highly reliable and efficient process. By utilizing structured databases, microservices, secure APIs, and automated control logic, the system ensures accurate tracking and rapid retrieval of medicines, surgical tools, laboratory materials, and emergency supplies.

The backend modules—such as authentication, inventory forecasting, error detection, sensor data handling, and communication with hospital information systems—work together to reduce human dependency and eliminate common issues like stockouts, misplacement, and delayed supply access. Real-time monitoring enhances decision-making, while automated alerts improve responsiveness during critical medical situations.

Overall, the backend architecture of ASRS offers a scalable and secure digital framework that supports smarter healthcare operations. Its adoption leads to optimized resource usage, reduced operational workload, and improved patient safety. With further integration of AI and predictive analytics, ASRS has the potential to become an essential part of future smart hospitals.

8. ACKNOWLEDGMENT

The authors would like to express their sincere gratitude to all those who contributed to the successful completion of this work. We extend our appreciation to the healthcare professionals and technical staff who provided valuable insights into current medical inventory management challenges. Their practical inputs greatly helped in shaping the design and backend implementation of the Automatic Storage and Retrieval System (ASRS).

We also thank our mentors, faculty members, and colleagues for their continuous guidance, encouragement, and constructive feedback throughout the study. Finally, we acknowledge the support of our institution for providing the resources and environment necessary for carrying out this research.

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