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Artificial Intelligence and Robotics for Automated Pharmacy and Medicine Dispensing Systems: A Survey

Abhijith T S[1], D H Aromal[1], S Nasif[1], Nithul Das H[1], Neethu S[2], Dr.Shani Raj[3]

Student, Department of Computer Science and Engineering, College of Engineering Kottarakkara, Kottarakkara, Kerala, India[1]

Assistant Professor, Department of Computer Science and Engineering, College of Engineering Kottarakkara, Kottarakkara, Kerala, India[2]

Associate Professor, Department of Computer Science and Engineering, College of Engineering Kottarakkara, Kottarakkara, Kerala, India[3]

Abstract: Manual medicine dispensing, drug storage, and pharmacy inventory management remain error-prone, slow, and labor-intensive, motivating a rapid rise in artificial intelligence (AI) and robotics research aimed at automating these processes. This paper presents a structured survey of twenty recent works (2020–2026) spanning robotic drug grasping, vision-based pill/drug identification, automated dispensers and infusion devices, IoT-enabled inventory and supply-chain tracking, and broader reviews of AI/deep-learning techniques underpinning these systems. We propose a four-category taxonomy – Robotic Grasping and Manipulation, Vision-Based Detection and Identification, Automated Dispensing and Delivery Hardware, and IoT/Inventory and Supply-Chain Management – and examine each reviewed paper in terms of technique, dataset, reported results, and trade-offs. A comparative analysis table summarizes accuracy, dataset scale, and system complexity across studies. Our findings show that YOLO-family detectors and hybrid grasp-planning networks dominate vision-guided manipulation, achieving 90–99% detection accuracy, while systematic reviews confirm consistent, though heterogeneous, gains in dispensing efficiency and medication safety from automation. We identify six open challenges, including limited real-world/clinical validation, dataset scarcity, edge-deployment constraints, and lack of standardized benchmarks, and outline future research directions to guide subsequent work in intelligent pharmacy automation.

Keywords: pharmacy automation, robotic grasping, medicine dispensing, YOLO, deep learning, IoT, healthcare robotics

I. INTRODUCTION

A. Background and Motivation

Medication errors arising from manual dispensing, mislabeling, and inventory mismanagement remain a significant patient-safety concern in hospitals and retail pharmacies worldwide. At the same time, pharmacy staff shortages, rising prescription volumes, and the operational pressures exposed by the COVID-19 pandemic have accelerated interest in automating repetitive, safety-critical pharmacy tasks [1], [9]. Advances in artificial intelligence (AI), machine learning (ML), and deep learning (DL), combined with maturing robotic manipulation and Internet of Things (IoT) sensing, now make it feasible to automate drug identification, picking and sorting, dispensing, infusion, and supply-chain tracking with a level of precision and consistency that manual processes struggle to match [1]. Object-detection architectures such as the YOLO family, deep reinforcement learning for grasp planning, and cloud-connected embedded sensing have each been applied, independently and in combination, to build smart pharmacy systems, vending machines, robotic delivery platforms, and infusion devices.

Despite substantial progress, published work is fragmented across robotics, computer vision, embedded systems, and clinical-pharmacy venues, using different datasets, metrics, and evaluation protocols. This fragmentation makes it difficult for a new researcher or practitioner to see the overall state of the art, compare techniques on a common footing, or identify where genuine research gaps remain.

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B. Need for this Survey

Several existing surveys address either general healthcare AI [5] or general robotic grasping [1], [15] without focusing specifically on the pharmacy/medicine-dispensing domain, and none of the reviewed papers jointly compares robotic drug grasping, vision-based pill identification, dispensing hardware, and IoT-based pharmaceutical inventory tracking within a single taxonomy. This survey addresses that gap by consolidating twenty recent, domain-relevant papers into a unified classification and comparative framework, enabling readers to quickly locate techniques relevant to a specific sub-problem (e.g., grasping overlapping pills vs. tracking cold-chain shipments) and to understand the trade-offs between accuracy, cost, and deployment complexity.

C. Contributions of this Paper

The main contributions of this survey are as follows:

1) We present a four-category taxonomy of AI/robotics-based pharmacy automation research, spanning robotic grasping, vision-based detection, dispensing hardware, and IoT/inventory management.
2) We analyze and compare 20 recent works (2020–2026), summarizing technique, dataset, key results, and pros/cons for each.
3) We construct a comparative analysis table contrasting accuracy, dataset scale, cost/hardware requirements, and system complexity across studies.
4) We identify six open challenges and corresponding future research directions to guide subsequent work in intelligent pharmacy automation.

D. Paper Organization

The remainder of this paper is organized as follows. Section II describes the survey methodology. Section III introduces the proposed taxonomy. Section IV reviews the literature by category. Section V presents the comparative analysis. Section VI discusses open challenges and future directions, and Section VII concludes the paper.

II. METHODOLOGY OF SURVEY

A. Data Sources

Candidate papers were identified using IEEE Xplore, ScienceDirect, SpringerLink, Wiley Online Library, PLOS ONE, MDPI (Electronics), and arXiv, supplemented by Google Scholar for cross-checking citation counts and venue quality.

B. Search Keywords

Searches combined domain and technique terms, including: “pharmacy automation”, “robotic drug grasping”, “medicine dispenser”, “smart pharmacy”, “pill detection YOLO”, “drug identification machine vision”, “IoT pharmaceutical supply chain”, “automated drug infusion”, and “AI healthcare robotics”.

C. Inclusion Criteria

Papers were included if they (i) were published between 2020 and 2026 as peer-reviewed journal articles or conference papers (with a small number of foundational/general reviews included for context), (ii) proposed or evaluated an AI, ML, DL, robotic, or IoT-based technique directly applicable to medicine/drug handling, dispensing, identification, or pharmaceutical logistics, and (iii) reported a method, dataset, or reviewed body of literature with identifiable results or conclusions.

D. Exclusion Criteria

Papers were excluded if they (i) addressed robotic grasping or object detection in entirely unrelated domains without applicability discussed to pharmacy/healthcare, (ii) were purely opinion pieces or news articles without technical content, or (iii) were inaccessible in full text for verification of methodology and results.

E. Total Papers Reviewed

A total of 20 papers met the inclusion criteria and form the basis of this survey, spanning 2020–2026, comprising 14 original technical/experimental studies and 6 review or meta-analysis papers.

III. TAXONOMY OF AI/ROBOTICS-BASED PHARMACY AUTOMATION

Based on the primary technical focus of each reviewed paper, we classify the literature into four categories, illustrated in Fig. 1.

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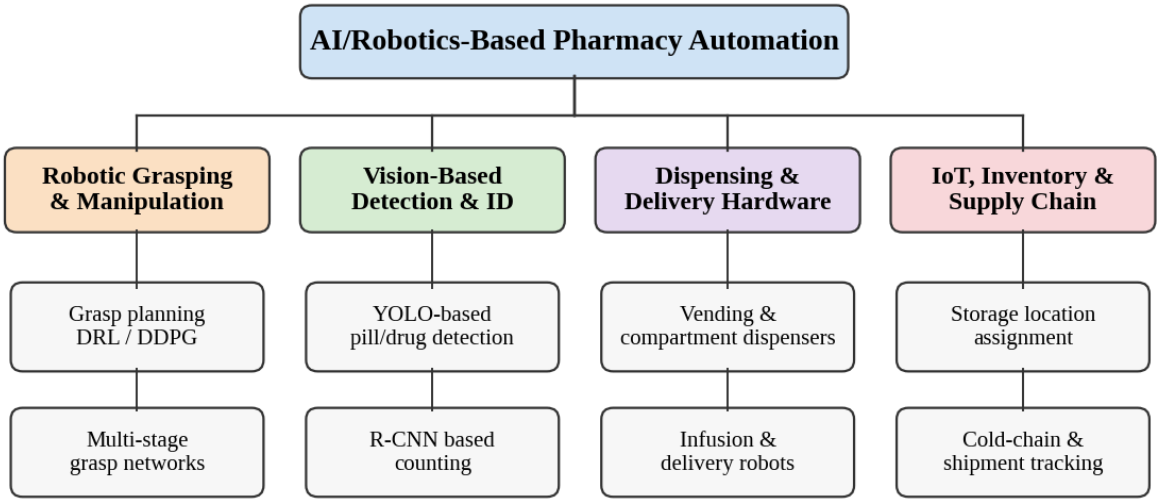


Fig. 1 Proposed taxonomy of AI/robotics-based pharmacy automation research.

A. Category 1: Robotic Grasping and Manipulation

This category covers deep-learning and reinforcement-learning approaches for planning and executing robotic grasps of drugs, pill packages, or general warehouse items, including handling of overlapping, cluttered, or novel objects.

B. Category 2: Vision-Based Detection and Identification

This category covers computer-vision pipelines – predominantly YOLO variants and region-based CNNs – used to detect, classify, count, or localize medicines, pill boxes, or pharmaceutical products for downstream sorting, dispensing, or warehouse management.

C. Category 3: Automated Dispensing and Delivery Hardware

This category covers electromechanical systems – vending machines, compartment-based dispensers, infusion devices, and mobile delivery robots – that physically deliver medication to patients or storage points, often integrating OCR, voice interfaces, or face recognition.

D. Category 4: IoT, Inventory, and Supply-Chain Management

This category covers IoT sensor networks, cloud analytics, and optimization algorithms used to track pharmaceutical inventory, storage conditions, and shipments, as well as data-driven storage-location assignment within automated pharmacies. It also includes broad AI/healthcare and AI/robotics review papers that provide cross-cutting context for the other three categories.

IV. LITERATURE REVIEW IN REVERSE CHRONOLOGICAL ORDER

Table I summarizes the twenty-paper corpus. The order follows publication year from newest to oldest; within the same year, closely related pharmacy automation and robotics studies are grouped for readability while retaining sequential IEEE citation numbering.

Alshmemri et al. (2026). Alshmemri et al. conduct a systematic review and meta-analysis of pharmacy automation across G20 countries. Their analysis provides pooled evidence concerning dispensing efficiency, medication safety, and user satisfaction. The study supports the broader adoption of automation while also highlighting substantial heterogeneity among the reviewed studies [10].

Sunantha and Pushpathi (2026). Sunantha and Pushpathi propose an IoT-enabled pharmaceutical inventory and supply-chain tracking system. The system integrates temperature sensors, GPS tracking, and cloud-based analytics to support real-time monitoring across inventory, procurement, transportation, and tracking activities. The approach improves supply-chain transparency, although its effectiveness depends on reliable connectivity [12].

Zhang and Lv (2025). Zhang and Lv combine a CNN-based grasp-point strategy with a penalty-constrained DDPG reinforcement-learning framework for autonomous drug retrieval. Their system demonstrates strong grasping

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performance for individual medicines, while performance decreases when multiple medicines overlap or when several targets are present. The study highlights the continuing difficulty of cluttered robotic manipulation [19].

Atienza et al. (2025). Atienza et al. develop an assistive robotic vision system using YOLOv5, a JetMax robotic arm, and an NVIDIA Jetson Nano. Their custom dataset contains 5,760 images across 20 medicine classes. The system achieves 90.67% machine-vision accuracy and 83.17% mechanical pick-and-place accuracy, demonstrating the practical combination of deep-learning detection and robotic manipulation [6].

Susila Sakthy et al. (2025). Susila Sakthy et al. introduce the Automated Medicine Dispenser Assistant (AMDA). The Raspberry Pi-based system uses face recognition to identify patients and dispense medication from ten compartments according to predefined schedules. The system focuses on improving medication adherence and reducing dosing errors, although its validation remains mainly at the prototype level [7].

Hossein et al. (2025). Hossein et al. provide a descriptive review of pharmacy automation and robotics. The study discusses Cartesian, SCARA, and articulated robotic systems and examines their applications in pharmaceutical environments. Its main contribution is providing a broad understanding of pharmacy robotics, although it does not provide the quantitative evaluation associated with experimental studies [9].

Tavakoli et al. (2025). Tavakoli et al. apply Faster R-CNN with a ResNet50 backbone to pharmaceutical product identification and counting. Using a dataset of 6,164 annotated images, the system achieves 98.84% identification accuracy and 98% counting accuracy. The results demonstrate strong recognition capability, although the two-stage architecture has higher computational requirements than lightweight detectors [11].

Uma Devi et al. (2025). Uma Devi et al. review the role of AI in healthcare, including electronic health records, AI symptom checkers, drug discovery, predictive health analysis, and telemedicine. The study provides useful background for understanding the wider role of AI in healthcare automation, although it is not focused specifically on robotic pharmacy systems [5].

Tang et al. (2024). Tang et al. propose a multi-stage smart-pharmacy grasping framework that combines SRCNN for image enhancement, YOLO-EASB for medicine segmentation, IAFFGA-net for grasp estimation, and an optimization algorithm for robotic trajectory planning. The system is designed to handle chaotic and overlapping drug arrangements and demonstrates the importance of integrating perception with physical manipulation [3].

Yang et al. (2024). Yang et al. develop an attribute-based encoder–decoder grasping network that combines workspace-image information with query-text embeddings using gated attention. The approach achieves 86.0% grasping success in simulation and 81.7% on unknown real-world objects. The study demonstrates that semantic information can help robots adapt to novel objects with limited additional data [4].

Kok et al. (2024). Kok et al. present an IoT-enabled embedded system for automated intravenous drug infusion. The system provides remote dosage registration and monitoring and reports an average infusion-volume error of approximately 6.5%. The results demonstrate the usefulness of connected monitoring while also showing that accuracy can be affected at very low infusion volumes [8].

Next-Generation Healthcare (2024). The Next-Generation Healthcare system proposes a Smart Prescription Medicine Vending Machine that combines OCR-based prescription scanning, voice recognition, automated dispensing, and inventory monitoring. The system aims to improve medicine accessibility and support continuous operation while reducing manual errors. However, the evidence remains primarily based on prototype implementation [13].

Hussain (2024). Hussain presents a comprehensive review of YOLO architectures from YOLOv1 to YOLOv8. The work examines architectural changes, benchmark performance, and applications across different domains. It provides a useful foundation for understanding the development of YOLO-based real-time detection systems used in pharmaceutical recognition [15].

Sun et al. (2024). Sun et al. propose an improved lightweight YOLOv8n model for pill-box detection and counting. The system uses ShuffleNetv2, VoVGSCSP, Wise-IoU v3, and pruning techniques. It achieves 95.6% mAP@0.5, reduces inference time, and produces a compact model suitable for edge devices such as the Raspberry Pi 4B [17].

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Li et al. (2023). Li et al. demonstrate the large-scale deployment of a learned pick-success predictor within Amazon Robotics' "Robin" fleet. The model was trained using more than 394,000 real production picks and was applied to large-scale package manipulation. Although the system is not pharmacy-specific, it provides strong evidence that learning-based grasp prediction can scale from laboratory settings to industrial production [2].

Soori et al. (2023). Soori et al. review AI, ML, and DL applications in advanced robotics. The study covers applications such as autonomous navigation, object recognition, manipulation, natural-language processing, and predictive maintenance. Its relevance to pharmacy automation lies in demonstrating the broader technological foundation on which intelligent healthcare robots can be developed [1].

Liu et al. (2022). Liu et al. propose a real-time medicine identification and positioning system that combines NanoDet with PP-OCR. The object detector first identifies candidate medicine bottles, after which text recognition extracts printed information from the detected regions. The fusion of visual and textual information enables more precise identification of specific medicine bottles for robotic grasping [14].

Hao et al. (2021). Hao et al. propose a data-driven storage assignment strategy for automated pharmacies. Their approach combines a BP neural network for storage-zone partitioning with Apriori association-rule mining to identify medicines that are likely to be stored together. The method demonstrates measurable improvements over traditional random storage assignment, although the evaluation is primarily numerical and simulation based [18].

Apostolescu et al. (2020). Apostolescu et al. present an automated medicament delivery mechanism designed to dispense tablets or pills at controlled doses and predetermined times. SolidWorks 3D CAD and motion simulation are used during development. The study demonstrates the feasibility of mechanical medication dispensing, although extensive physical and clinical validation is not reported [16].

Kavirayani et al. (2020). Kavirayani et al. develop a robotic medicine-delivery system using sensors and indicator-based navigation. A Firebird-V robot is used to test the navigation algorithm in a prototype laboratory arena. The system demonstrates autonomous ward navigation and medicine delivery while attempting to avoid collisions, providing an early example of robotic medicine transportation [20].

V. COMPARATIVE ANALYSIS

Table I summarizes all twenty reviewed papers across publication year, category, primary technique, dataset or evidence base, best-reported result, and qualitative cost or complexity. Fig. 2 visualizes reported accuracy for the subset of papers that provide directly comparable numerical detection or grasping metrics.

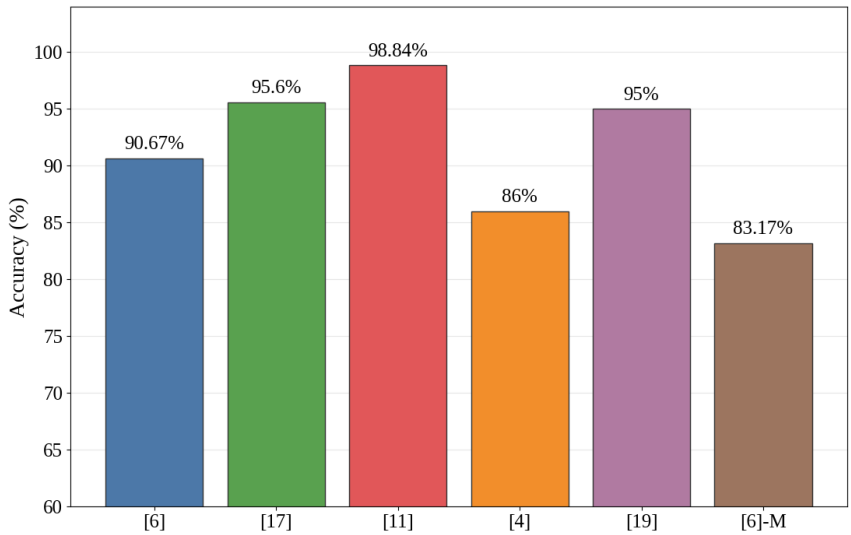


Fig. 2 Reported best-case accuracy for representative vision and robotic grasping papers. Reference numbers are shown in brackets; [6]-M denotes the mechanical pick-and-place accuracy reported by [6].

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TABLE I COMPARATIVE ANALYSIS OF REVIEWED PAPERS

No.	Paper	Year	Category	Technique	Dataset / Evidence Base	Best Result	Complexity
1	Alshmemri et al. [10]	2026	Review	Systematic review + meta-analysis	G20 hospital studies	Positive pooled effects	N/A
2	Sunantha & Pushpathi [12]	2026	IoT	IoT + GPS + cloud analytics	Prototype system	Improved transparency	Medium
3	Zhang & Lv [19]	2025	Grasping	CNN + DDPG RL	Public + real drug set	~95% grasp success	High
4	Atienza et al. [6]	2025	Detection + hardware	YOLOv5 + JetMax	5,760 images, 20 classes	90.67% vision / 83.17% pick	Medium
5	Susila Sakthy et al. [7]	2025	Dispensing	Face recognition + Raspberry Pi	10-slot prototype	Functional prototype	Low–Medium
6	Hossein et al. [9]	2025	Review	Pharmacy robotics review	Literature + cases	Qualitative synthesis	N/A
7	Tavakoli et al. [11]	2025	Detection	Faster R-CNN + ResNet50	6,164 images	98.84% ID / 98% counting	High
8	Uma Devi et al. [5]	2025	Review	AI/ML/DL review	Literature	Qualitative synthesis	N/A
9	Tang et al. [3]	2024	Grasping	SRCNN + YOLO-EASB + IAFFGA-net + PSO	Custom drug-image set	Improved accuracy/efficiency	High
10	Yang et al. [4]	2024	Grasping	Encoder–decoder + gated attention	Simulation + real objects	86.0% sim / 81.7% real	Medium
11	Kok et al. [8]	2024	Dispensing	IoT infusion control	Bench infusion trials	~6.5% volume error	Medium
12	Next-Gen Healthcare [13]	2024	Dispensing	OCR + voice + motor/spring	Prototype system	Functional prototype	Medium
13	Hussain [15]	2024	Review	YOLOv1–v8 review	Literature + benchmarks	Comparative synthesis	N/A
14	Sun et al. [17]	2024	Detection	Improved YOLOv8n + pruning	Pill-box dataset	95.6% mAP@0.5	Low
15	Li et al. [2]	2023	Grasping	Learned pick-success predictor	394K+ production picks	Large-scale deployment	High
16	Soori et al. [1]	2023	Review	AI/ML/DL survey	Literature	Qualitative synthesis	N/A
17	Liu et al. [14]	2022	Detection + grasping	NanoDet + PP-OCR	Hospital medicine scenes	Reliable object localization	Medium
18	Hao et al. [18]	2021	Storage optimization	Hungarian + Apriori + BP-NN	Numerical simulation	Better than random assignment	Medium
19	Apostolescu et al. [16]	2020	Dispensing hardware	Mechanical dispensing + CAD	CAD / motion simulation	Simulated feasibility	Low
20	Kavirayani et al. [20]	2020	Delivery hardware	Sensor navigation + Firebird-V	Laboratory prototype	Successful delivery	Medium

Insights from Table I: (i) The literature shows a clear progression from individual mechanical dispensing and robotic delivery systems toward integrated AI-based perception, manipulation, and connected pharmacy management.

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(ii) Vision-based detection studies report the most directly comparable numerical results. Faster R-CNN [11], improved YOLOv8n [17], and YOLOv5-based medicine recognition [6] demonstrate accuracy levels ranging from approximately 90% to 99%.
(iii) Lightweight YOLO-based systems [6], [17] provide an attractive balance between accuracy and computational efficiency. In particular, the improved YOLOv8n model achieves 95.6% mAP@0.5 while maintaining a compact model suitable for edge hardware.
(iv) Two-stage detection using Faster R-CNN [11] achieves higher identification and counting accuracy but requires greater computational resources. This illustrates the recurring trade-off between recognition accuracy and deployment efficiency.
(v) Robotic grasping studies [3], [4], [19] demonstrate that accurate medicine detection alone is insufficient for complete pharmacy automation. Successful operation also requires grasp-point estimation, trajectory planning, and adaptive manipulation. Overlapping and multi-target medicines remain difficult.
(vi) Multimodal recognition using object detection and OCR [14] provides an additional layer of semantic identification. Using package text along with visual information can help distinguish medicines that have similar physical appearances.
(vii) Automated dispensing and delivery systems [7], [13], [16], [20] demonstrate that pharmacy automation can be implemented using relatively affordable embedded hardware and mechanical systems. However, most reported evaluations remain limited to prototypes, simulations, or controlled laboratory environments.
(viii) IoT-based approaches [8], [12], [18] extend automation to inventory, storage, infusion monitoring, and supply-chain management. These systems can improve transparency and efficiency, but their reliability depends on connectivity, sensor accuracy, and continuous data availability.
(ix) Overall, the reviewed literature indicates that the future of smart pharmacy automation lies in integrating computer vision, robotic manipulation, automated dispensing, inventory management, and verification into a single reliable workflow. A major research gap remains the limited real-world validation of complete end-to-end pharmacy automation systems.

VI. CHALLENGES AND FUTURE DIRECTIONS

Challenge 1: Limited real-world/clinical validation. Most robotic and dispensing prototypes (e.g., [7], [16], [20]) are validated only in laboratory arenas or via simulation. *Future Direction:* Conduct multi-site clinical pilot studies with standardized safety and usability metrics before large-scale deployment.

Challenge 2: Small, custom, non-standardized datasets. Vision-based studies [6], [11], [17] rely on custom datasets of 4,000–6,000 images collected under a single environment, risking overfitting and poor generalization. *Future Direction:* Develop and publicly release large, multi-institution, multi-lighting pharmaceutical image benchmarks analogous to COCO/ImageNet for the drug-detection domain.

Challenge 3: Degraded performance on cluttered, overlapping, or multi-target scenes. Grasping papers [3], [19] report accuracy drops for overlapping or multiple simultaneous targets. *Future Direction:* Investigate 3D/point-cloud-based grasp planning and multi-object-aware reinforcement learning to improve clutter robustness.

Challenge 4: Edge-deployment and computational constraints. High-accuracy models such as Faster R-CNN [11] and multi-stage pipelines [3] are computationally expensive, limiting real-time use on low-cost embedded hardware. *Future Direction:* Extend lightweight pruning/distillation techniques (as in [17]) to two-stage and RL-based methods to enable low-latency edge deployment.

Challenge 5: Dependence on connectivity and auxiliary recognition modules. IoT-tracking [12] and OCR/voice-driven dispensers [8], [13] depend on continuous connectivity or auxiliary recognition accuracy that is not always fully characterized. *Future Direction:* Design offline-capable fallback modes and report auxiliary-module error rates (OCR, voice, face recognition) under realistic noise/lighting conditions.

Challenge 6: Heterogeneity and lack of standardized evaluation. The meta-analysis by Alshmemri et al. [10] highlights substantial heterogeneity across automation studies, and no reviewed paper uses a common benchmark suite across categories. *Future Direction:* Establish standardized evaluation protocols and shared benchmark datasets/metrics (accuracy, cost, latency, safety) spanning grasping, detection, and dispensing sub-domains to enable fair cross-study comparison.



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VII. CONCLUSION

This survey reviewed 20 recent papers (2020–2026) on AI- and robotics-based pharmacy automation, organized into a four-category taxonomy covering robotic grasping, vision-based detection, dispensing hardware, and IoT/inventory management. The comparative analysis shows that vision-based detectors, particularly lightweight YOLO variants, achieve the highest and most reproducible accuracy (90–99%) while remaining deployable on low-cost edge hardware, whereas grasping and dispensing systems still require substantial real-world validation. Systematic reviews corroborate positive but heterogeneous efficiency and safety gains from automation at a population level. Six key challenges – limited clinical validation, dataset scarcity, clutter handling, edge-deployment constraints, connectivity dependence, and lack of standardized benchmarks – were identified as priority areas for future work. These findings and the accompanying taxonomy are intended to guide the design of a subsequent project combining vision-based drug identification with robotic grasping and IoT-based tracking into an integrated smart-pharmacy system.

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