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Research Article

Machine Learning-Based Framework for Automated Drug Detection and Visual Recognition in Self-Images

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Abstract

The increasing complexity of medication usage, drug misidentification, and dispensing-related errors has created a significant demand for intelligent systems capable of automated pharmaceutical recognition. Traditional approaches for identifying drugs rely heavily on manual inspection, prescription interpretation, and human expertise, which may introduce delays and inaccuracies. This research presents a machine learning-based framework for automated drug detection and visual recognition in self-images, designed to identify pharmaceutical products from user-captured images through advanced visual feature extraction, classification, and recognition mechanisms. The proposed framework integrates image preprocessing, object detection, feature representation, and machine learning-based classification to enhance medication identification efficiency. The study conceptually investigates how artificial intelligence can support safer medication practices by reducing recognition errors and improving accessibility to drug information. Existing research on medication errors, prescription recognition, and pharmaceutical image analysis highlights the need for automated solutions that combine computer vision with intelligent decision-making capabilities (Gates et al., 2019; Nayak et al., 2023). Furthermore, human-centered AI trust modeling principles emphasize the importance of reliable and interpretable intelligent systems when applied to critical domains such as healthcare (Ramamurthy et al., 2026). The framework addresses current limitations in manual drug identification by providing a scalable approach for real-world applications, including personal medication management, pharmacy assistance, and healthcare support systems. The research contributes a structured machine learning architecture for improving drug recognition accuracy, reducing medication-related risks, and strengthening intelligent healthcare technologies.

Keywords: Machine Learning, Drug Detection, Image Recognition, Computer Vision, Medication Safety, Pharmaceutical Identification, Artificial Intelligence, Healthcare Automation, Feature Engineering.

INTRODUCTION

Background

Medication identification is a fundamental component of safe healthcare delivery because accurate recognition of pharmaceutical products directly influences appropriate usage, prescription compliance, and prevention of medication-related risks. With the increasing availability of diverse pharmaceutical products, visually similar drug packaging, and complex medication processes, accurate drug recognition has become a challenging task. Human-based identification methods often depend on reading labels, interpreting packaging information, and verifying drug characteristics manually, creating possibilities for confusion and errors.

Medication errors represent a critical healthcare concern because incorrect identification, dispensing mistakes, and inappropriate medication administration can negatively affect patient safety. Gates et al. (2019) emphasized the importance of standardized classification approaches for understanding medication-related harm and improving error management practices. Similarly, Mekonnen et al. (2018) identified medication errors and adverse drug events as significant challenges within healthcare systems, particularly where systematic monitoring and preventive technologies remain limited.

Recent developments in artificial intelligence (AI), machine learning (ML), and computer vision provide opportunities to automate pharmaceutical recognition through visual analysis. Machine learning algorithms can analyze image-based information, extract meaningful patterns, and classify pharmaceutical objects without requiring continuous human intervention. In this context, self-image-based drug recognition refers to a user-oriented approach where individuals capture images of medicines using personal devices, allowing intelligent systems to analyze and identify drug characteristics.

The integration of machine learning into medication recognition requires not only high classification accuracy but also reliability, transparency, and user trust. Ramamurthy et al. (2026) demonstrated that human-AI trust modeling through ensemble learning and advanced feature engineering is essential for cognitive intelligent systems. Such principles are particularly relevant in healthcare environments where incorrect predictions may have direct consequences.

Problem Statement

Although pharmaceutical information systems have improved medication management, many existing identification processes still rely on manual verification. Patients and healthcare assistants may experience difficulty identifying medicines when labels are unclear, packaging information is unavailable, or multiple products have similar visual characteristics. Prescription recognition and pharmaceutical inventory studies demonstrate progress in automated recognition; however, limitations remain regarding real-world image variations, environmental conditions, and user-generated images (Kumar & Chuli, 2023; Nayak et al., 2023).

Self-captured drug images introduce additional challenges, including inconsistent lighting, different camera resolutions, background noise, image orientation variations, and partial visibility of medication packaging. Conventional image processing approaches may struggle under these conditions, requiring intelligent frameworks capable of adaptive feature learning and robust classification.

Therefore, a machine learning-based framework is required to establish an automated, accurate, and scalable mechanism for drug detection from self-images. Such a system can support medication safety by assisting users, pharmacists, and healthcare providers in identifying pharmaceutical products efficiently.

Research Relevance

The application of machine learning for drug detection represents an intersection between healthcare automation, computer vision, and intelligent decision-support systems. Previous research has demonstrated the effectiveness of AI-based recognition methods in pharmaceutical applications. Kumar and Chuli (2023) explored the optimization of pharmaceutical inventory management using YOLOv7 and OCR techniques, highlighting the potential of deep learning-based visual recognition for medicine-related tasks. Similarly, Nayak et al. (2023) reviewed machine learning approaches for medical prescription recognition, demonstrating the growing role of AI in transforming medication information processing.

However, most existing studies focus on controlled environments such as inventory systems or prescription processing. A self-image-based framework introduces a more user-centered perspective by enabling recognition under uncontrolled real-world conditions. This research direction is relevant because it extends AI-based pharmaceutical recognition from institutional environments toward personal healthcare assistance.

Objectives

The primary objectives of this research are:

1. To develop a conceptual machine learning framework for automated drug detection using self-captured images.

2. To analyze image processing and feature extraction strategies suitable for pharmaceutical recognition.

3. To investigate the role of machine learning classification techniques in improving drug identification accuracy.

4. To examine the potential contribution of intelligent drug recognition systems toward reducing medication-related errors.

5. To identify limitations and future research directions for AI-based pharmaceutical recognition systems.

Scope and Significance

The scope of this research focuses on developing a machine learning-based architecture capable of recognizing pharmaceutical products from visual inputs. The framework considers image acquisition, preprocessing, feature extraction, classification, and decision-support mechanisms.

The significance of the proposed approach lies in its ability to improve accessibility and safety in medication management. A reliable drug recognition system may assist individuals with medication identification, support pharmacists during verification processes, and contribute to healthcare automation. However, the framework must maintain high reliability because inaccurate recognition in healthcare environments can create potential risks. Therefore, incorporating trustworthy AI principles and robust validation mechanisms remains essential (Ramamurthy et al., 2026).

LITERATURE REVIEW

Machine Learning Applications in Medication Recognition

Research on medication safety has increasingly focused on reducing human errors through intelligent technologies. Chowdhury et al. (2006) examined drug usage practices and highlighted the importance of rational medication management. Their findings emphasize that correct drug identification is an essential component of appropriate medication utilization. Although the study primarily focused on drug use perspectives, it establishes the broader importance of improving medication-related decision processes.

Medication errors have been extensively investigated as a healthcare safety challenge. Gates et al. (2019) proposed the Harm Associated with Medication Error Classification

(HAMEC) approach to standardize the assessment of medication-related harm. Their work demonstrates that understanding error patterns is necessary for designing preventive systems. A machine learning-based drug recognition framework aligns with this objective by attempting to reduce one category of medication risk: incorrect identification.

Koumpagioti et al. (2014) analyzed medication processes in pediatric patients and identified vulnerabilities within medication administration workflows. Their findings indicate that medication processes involve multiple stages where errors may occur, including preparation, administration, and verification. Automated recognition systems can provide additional verification support by assisting users during drug identification.

Computer Vision-Based Pharmaceutical Recognition

Recent advances in computer vision have enabled automated recognition of objects through image-based learning. Kumar and Chuli (2023) demonstrated the effectiveness of YOLOv7 and OCR-based approaches for pharmaceutical inventory management. Their research highlights how object detection algorithms can locate medicine-related objects while optical character recognition can extract textual information from packaging.

However, inventory-based recognition systems generally operate within structured environments. Self-image recognition introduces greater complexity because images are captured by users under uncontrolled conditions. Variations in image quality, perspective, and environmental factors require more adaptive machine learning architectures.

Martinez-Martin et al. (2021) explored visual recognition through an aerial robotic system designed for inventory and localization tasks. Although their research was not focused on pharmaceuticals, it demonstrates the broader capability of computer vision systems to identify and localize objects within dynamic environments. These principles can be adapted for drug image recognition applications.

Prescription Recognition and Intelligent Healthcare Systems

Nayak et al. (2023) reviewed machine learning techniques for medical prescription recognition and identified the increasing role of AI in healthcare documentation and interpretation. Their work demonstrates that machine learning models can process complex medical information and support automated healthcare workflows.

The transition from prescription recognition to drug image recognition requires additional challenges to be addressed. Prescription systems primarily analyze written information, whereas drug detection systems must interpret visual characteristics such as shape, packaging, color patterns, and textual indicators. Therefore, combining visual feature learning with classification models becomes essential.

Medication Error Prevention and AI Reliability

Mekonnen et al. (2018) highlighted the prevalence of adverse drug events and medication errors, emphasizing the need for systematic interventions. Automated drug recognition systems represent one possible preventive strategy by providing an additional verification layer before medication use.

Tariq et al. (2024) discussed medication dispensing errors and prevention strategies, reinforcing the importance of accurate identification during pharmaceutical handling. AI-based recognition frameworks can complement existing safety procedures by reducing dependence on manual verification alone.

Nevertheless, healthcare AI systems must address reliability concerns. Ramamurthy et al. (2026) emphasized that human-AI trust depends on effective feature engineering, reliable prediction mechanisms, and transparent decision processes. For drug recognition applications, users must understand and trust system outputs before relying on automated recommendations.

Research Gap and Theoretical Positioning

The reviewed literature demonstrates significant progress in medication safety, prescription recognition, and pharmaceutical image analysis. However, a research gap exists in developing user-centered machine learning frameworks specifically designed for self-image-based drug detection. Existing approaches commonly focus on inventory environments, prescription processing, or structured image datasets.

The proposed framework positions itself within the theoretical foundation of intelligent healthcare automation, where machine learning serves as a decision-support mechanism rather than a complete replacement for professional judgment. By integrating computer vision, feature engineering, and trustworthy AI principles, the framework aims to provide an adaptive solution for safer medication identification.

METHODOLOGY

3.1 Proposed Machine Learning-Based Drug Detection Framework

This research proposes a machine learning-based framework for automated drug detection and visual recognition from self-captured images. The framework is designed as an intelligent healthcare support architecture that transforms raw user-generated images into meaningful pharmaceutical identification outputs. Unlike conventional drug verification methods that depend entirely on human interpretation, the proposed approach integrates computer vision, machine learning classification, and intelligent feature analysis to improve recognition efficiency.

The framework follows a multi-stage pipeline consisting of image acquisition, preprocessing, visual feature extraction, object localization, classification, and decision-support generation. Each stage contributes to improving recognition reliability while addressing practical challenges associated with self-image-based pharmaceutical detection.

The conceptual architecture consists of five major layers:

1. Image Acquisition Layer
2. Image Enhancement and Preprocessing Layer
3. Feature Extraction and Representation Layer
4. Machine Learning-Based Classification Layer
5. Intelligent Verification and Decision Support Layer

3.2 Image Acquisition Layer

The first stage involves collecting self-images of pharmaceutical products captured through smartphones, tablets, or digital cameras. The purpose of this layer is to provide a flexible mechanism through which users can submit images without requiring specialized equipment.

Unlike laboratory-controlled datasets, self-images contain real-world variations including different illumination conditions, camera angles, image resolution differences, background interference, and partial object visibility. Therefore, the framework considers user-generated image variability as a fundamental design challenge.

The image acquisition layer captures important visual information such as:

• Medicine packaging structure

• Tablet or capsule appearance

• Brand indicators

• Printed labels

• Shape and color characteristics

• Container design

This approach aligns with the broader objective of improving medication accessibility and reducing identification errors highlighted in medication safety research (Chowdhury et al., 2006).

3.3 Image Enhancement and Preprocessing Layer

Raw images cannot directly be processed effectively by machine learning algorithms because they often contain unwanted variations. The preprocessing stage improves image quality by preparing input data for feature extraction.

The major preprocessing operations include:

Image Normalization

Image normalization adjusts differences in brightness, contrast, and scale. This process ensures that the model receives consistent visual patterns regardless of the original capturing environment.

Noise Reduction

Self-captured images may contain background noise caused by camera limitations or environmental conditions. Noise reduction techniques improve the visibility of important pharmaceutical features.

Image Segmentation

Segmentation separates the drug object from surrounding background information. Accurate segmentation is essential because irrelevant visual elements may reduce classification performance.

Data Augmentation

To improve model generalization, image augmentation strategies can generate modified training samples through rotation, scaling, flipping, and brightness variation. This enables the model to learn diverse pharmaceutical appearances.

The importance of robust preprocessing is supported by previous machine learning-based recognition approaches where visual quality directly influences classification accuracy (Kumar & Chuli, 2023).

3.4 Feature Extraction and Representation Layer

Feature extraction represents the transformation of image information into numerical patterns that machine learning models can interpret. The effectiveness of drug recognition depends heavily on the ability to identify meaningful visual characteristics.

The proposed framework considers three categories of features:

Visual Structural Features

These include:

• Shape characteristics

• Size information

• Tablet and capsule geometry

• Packaging structure

Structural features assist in distinguishing visually similar pharmaceutical products.

Textual Features

Drug images frequently contain printed information such as:

• Medicine name

• Manufacturer details

• Dosage information

• Chemical composition

Optical character recognition (OCR) techniques can extract textual information from packaging surfaces. Kumar and Chuli (2023) demonstrated that combining object detection with OCR improves pharmaceutical information extraction.

Deep Feature Representations

Deep learning-based feature extraction allows the system to automatically learn complex patterns from images. Instead of manually defining every visual characteristic, deep neural networks identify high-level representations that improve recognition capability.

This approach supports the development of adaptive systems capable of handling diverse pharmaceutical appearances.

3.5 Machine Learning-Based Classification Model

The classification layer represents the central intelligence component of the proposed framework. After feature extraction, the system applies machine learning algorithms to categorize the detected pharmaceutical object.

The framework may integrate ensemble learning and deep learning classification strategies. Ensemble-based approaches combine multiple predictive models to improve reliability by reducing individual model limitations.

A generalized classification process involves:

Input Image → Extracted Features → Classification Model → Predicted Drug Category → Confidence Score

The model evaluates similarities between extracted image characteristics and previously learned pharmaceutical patterns. The final output includes the predicted drug identity and confidence estimation.

The importance of reliable classification is consistent with trustworthy AI principles. Ramamurthy et al. (2026) emphasized that human-AI trust depends on advanced feature engineering and reliable intelligent decision-making mechanisms. In healthcare applications, confidence estimation becomes particularly important because users require assurance before accepting automated predictions.

3.6 Intelligent Verification and Decision Support Layer

The final layer converts machine learning predictions into meaningful healthcare assistance. Instead of providing only a classification label, the framework generates additional verification information.

Possible outputs include:

• Identified drug name

• Visual similarity score

• Packaging confirmation

• Recognition confidence level

• Safety warnings

• Recommendation for professional verification when uncertainty is high

This layer prevents overdependence on automated decisions and maintains human oversight. Such an approach is important because medication-related decisions require accuracy and responsibility.

3.7 Proposed Algorithmic Workflow

The operational workflow of the framework can be summarized as:

Step 1: User captures an image of the pharmaceutical product.

Step 2: The system performs image preprocessing to remove noise and improve quality.

Step 3: Computer vision techniques detect the pharmaceutical object within the image.

Step 4: Feature extraction algorithms identify visual and textual characteristics.

Step 5: Machine learning models compare extracted patterns with trained pharmaceutical representations.

Step 6: The classification system generates a predicted drug identity with confidence measurement.

Step 7: The verification layer provides user-oriented information and safety recommendations.

3.8 Model Evaluation Strategy

The effectiveness of the proposed framework can be evaluated using standard machine learning performance indicators:

Accuracy

Measures the percentage of correctly identified pharmaceutical samples.

Precision

Determines the correctness of positive drug identification results.

Recall

Evaluates the ability of the system to detect relevant drug classes.

F1-Score

Balances precision and recall performance.

Classification Confidence

Measures the reliability of model predictions.

Evaluation should also consider practical factors such as image quality variation, recognition speed, and robustness under different environmental conditions.

3.9 Ethical and Practical Considerations

Although automated drug recognition provides significant benefits, several limitations require consideration. Incorrect identification may lead to inappropriate medication usage; therefore, the framework should function as a support tool rather than a replacement for pharmacists or healthcare professionals.

Data privacy represents another important concern because self-images may contain sensitive healthcare-related information. Secure data handling, anonymization, and responsible AI practices are necessary for deployment.

Furthermore, pharmaceutical diversity creates challenges because new medicines, packaging modifications, and regional variations may reduce model performance. Continuous model updating and validation are required to maintain reliability.

RESULTS

The conceptual evaluation of the proposed machine learning-based drug detection framework indicates several important findings regarding automated pharmaceutical recognition. The framework demonstrates the potential of integrating computer vision and machine learning techniques to improve medication identification efficiency.

The first major finding is that visual recognition technologies can provide an effective alternative support mechanism for traditional manual drug identification. Existing medication safety research highlights that human errors during medication processes remain a significant challenge (Gates et al., 2019; Mekonnen et al., 2018). By introducing automated image-based recognition, the proposed framework can reduce dependence on manual inspection and provide additional verification support.

The second finding relates to the importance of combining multiple information sources. Image-only recognition may face difficulties when pharmaceutical products have similar appearances. However, integrating structural visual features with OCR-based textual extraction improves identification reliability. Previous research on pharmaceutical inventory optimization demonstrated that combining object detection and text recognition enhances medicine identification capabilities (Kumar & Chuli, 2023).

The framework also reveals that self-image-based recognition requires stronger adaptability compared with controlled pharmaceutical recognition environments. User-generated images introduce unpredictable variations, including lighting changes, image distortion, and incomplete visibility. Therefore, preprocessing and deep feature learning mechanisms are essential components for maintaining model robustness.

Another important finding is the significance of trustworthy artificial intelligence in healthcare applications. A high-performing model alone is insufficient because users must understand and trust system recommendations. The principles of human-AI trust modeling emphasize that intelligent systems require reliable feature engineering and interpretable decision processes (Ramamurthy et al., 2026). The proposed framework incorporates confidence estimation and verification mechanisms to improve user acceptance.

The analysis further indicates that machine learning-based drug recognition can contribute to reducing medication-related risks across multiple environments. In personal healthcare settings, the system can assist individuals in identifying unknown medicines. In pharmacy environments, it can provide additional verification during dispensing activities. These applications directly address concerns related to medication dispensing errors and prevention strategies (Tariq et al., 2024).

However, the findings also identify several limitations. The performance of the system depends heavily on training data quality and pharmaceutical image diversity. A model trained on limited datasets may fail to recognize new products or region-specific packaging variations. Additionally, automated predictions require continuous validation because incorrect recognition may create safety risks.

Overall, the findings suggest that the proposed framework provides a promising foundation for intelligent pharmaceutical recognition. By combining machine learning, computer vision, and trustworthy AI principles, the system can enhance medication identification while maintaining appropriate human oversight.

DISCUSSION

The development of a machine learning-based framework for automated drug detection and visual recognition in self-images represents a significant advancement toward intelligent medication management. The findings demonstrate that artificial intelligence can support safer pharmaceutical identification by transforming conventional manual recognition processes into automated, data-driven workflows. However, successful implementation requires careful consideration of technical reliability, healthcare safety, user trust, and operational limitations.

A major implication of this research is the potential reduction of medication identification errors. Previous studies have highlighted that medication errors occur across different stages of healthcare processes, including prescribing, dispensing, and administration (Gates et al., 2019; Mekonnen et al., 2018). The proposed framework addresses one critical point in this chain by providing automated visual verification before medication use. Rather than replacing healthcare professionals, the system functions as an additional intelligence layer that supports decision-making and minimizes avoidable mistakes.

The integration of computer vision and machine learning provides several advantages over traditional identification approaches. Manual drug identification requires users to interpret labels, recognize packaging, and compare pharmaceutical characteristics. Such processes may become difficult when medicine packaging is damaged, text is unclear, or multiple drugs share similar appearances. The proposed framework improves this process by analyzing multiple characteristics simultaneously, including visual patterns, object structure, and extracted text information. This multi-feature approach is consistent with previous pharmaceutical recognition research where combining detection algorithms with OCR techniques improved medicine identification capabilities (Kumar & Chuli, 2023).

Another important contribution is the movement toward user-centered healthcare artificial intelligence. Many existing pharmaceutical technologies focus on institutional applications such as pharmacy inventory management or prescription processing. In contrast, self-image-based recognition expands accessibility by enabling individuals to interact directly with intelligent healthcare systems. This approach can be particularly beneficial in situations where users need immediate assistance in identifying medication products.

Theoretical analysis suggests that trustworthy AI principles are essential for healthcare-focused machine learning systems. Although classification accuracy is a fundamental performance factor, user confidence and system transparency are equally important. Ramamurthy et al. (2026) emphasized that human-AI trust depends on advanced feature engineering, reliable learning mechanisms, and effective cognitive interaction between users and intelligent systems. Applying these principles to drug recognition ensures that automated predictions are not blindly accepted but evaluated through confidence-based verification mechanisms.

Despite these advantages, several trade-offs exist. Increasing model complexity through advanced deep learning architectures may improve recognition accuracy but can also increase computational requirements. Lightweight models may provide faster response times but could reduce performance under challenging image conditions. Therefore, system developers must balance accuracy, efficiency, and accessibility depending on deployment environments.

Data availability represents another significant limitation. Pharmaceutical recognition models require diverse and representative image datasets containing different drug types, packaging designs, manufacturers, and environmental conditions. Limited training data may reduce the ability of the system to recognize uncommon medicines. Additionally, pharmaceutical products continuously change due to packaging updates and market variations, requiring regular model retraining and validation.

The framework also raises ethical considerations related to healthcare responsibility and data privacy. Self-images of medicines may indirectly reveal personal health information. Therefore, secure data management, privacy-preserving machine learning techniques, and responsible deployment strategies are necessary. Automated drug recognition should remain a supportive technology rather than a definitive medical authority.

Comparison with existing literature reveals that previous studies primarily addressed individual components of medication safety, including drug usage analysis (Chowdhury et al., 2006), medication process evaluation (Koumpagioti et al., 2014), prescription recognition (Nayak et al., 2023), and dispensing error prevention (Tariq et al., 2024). The proposed framework extends these contributions by integrating visual recognition, machine learning classification, and intelligent verification into a unified architecture.

Overall, the discussion indicates that machine learning-based drug detection has strong potential to improve pharmaceutical safety and accessibility. However, future development should focus on improving dataset diversity, enhancing model interpretability, strengthening privacy protection, and establishing clinical validation procedures before large-scale deployment.

CONCLUSION

This research presented a machine learning-based framework for automated drug detection and visual recognition in self-images, addressing the growing need for intelligent solutions in pharmaceutical identification and medication safety. The proposed framework integrates computer vision, feature extraction, machine learning classification, and intelligent verification mechanisms to provide an automated approach for recognizing drugs from user-captured images.

The study highlights that medication errors and drug misidentification remain important healthcare challenges requiring innovative technological interventions. Existing research has demonstrated the importance of improving medication processes, reducing dispensing errors, and implementing intelligent recognition approaches (Gates et al., 2019; Mekonnen et al., 2018; Tariq et al., 2024). By extending these concepts into a self-image-based recognition framework, this research provides a user-oriented approach that enhances accessibility and supports safer medication practices.

The proposed architecture contributes to the field by combining visual analysis and machine learning-based decision support within a single framework. Unlike conventional approaches that rely mainly on manual verification, the system can analyze pharmaceutical characteristics automatically and provide recognition assistance. The integration of OCR-based information extraction and visual feature learning further improves the possibility of accurate identification, building upon previous pharmaceutical recognition approaches (Kumar & Chuli, 2023).

A significant contribution of this research is the emphasis on trustworthy artificial intelligence. Healthcare applications require not only accurate predictions but also reliability, transparency, and user confidence. Incorporating human-AI trust principles ensures that intelligent systems remain dependable and responsibly integrated into healthcare workflows (Ramamurthy et al., 2026).

Despite its potential, the framework has limitations related to dataset availability, environmental image variations, computational requirements, and ethical concerns. Future research should focus on developing large-scale pharmaceutical image datasets, improving adaptive learning capabilities, integrating explainable AI mechanisms, and conducting real-world validation studies.

In conclusion, the proposed machine learning-based drug detection framework represents a promising direction for intelligent healthcare automation. By supporting accurate pharmaceutical recognition and reducing dependence on manual identification, such systems can contribute to safer medication management, improved healthcare accessibility, and more efficient digital health ecosystems.

REFERENCES

1. Chowdhury, F. R., Rahman, M. M., Huq, M. F., & Begum, S.(2006). Rationality of drug uses: Its Bangladeshi perspectives.Mymensingh Medical Journal,15(2), 215–219.

2. Gates, P. J., Baysari, M. T., Mumford, V., Raban, M. Z., & Westbrook, J. I. (2019). Standardising the classification of harm associated with medication errors: The harm associated with medication error classification (HAMEC).Drug Safety,42(8), 931–939.

3. Koumpagioti, D., Varounis, C., Kletsiou, E., Nteli, C., & Matziou, V. (2014). Evaluation of the medication process in pediatric patients: A meta-analysis.Jornal de Pediatria,90(4), 344–355.

4. Kumar, S., & Chuli, A. (2023). Optimizing pharmaceutical inventory management with YoloV7 and easy OCR on medicine strips.International Journal of Science and Research,12(8), 1662–1669.

5. Martinez-Martin, E., Ferrer, E., Vasilev, I., & del Pobil, A. P.(2021). The UJI aerial librarian robot: A quadcopter for visual library inventory and book localisation.Sensors,21(4), 1079.

6. Mekonnen, A. B., Alhawassi, T. M., McLachlan, A. J., & Brien, J. A. E. (2018). Adverse drug events and medication errors in African hospitals: A systematic review.Drugs-Real World Outcomes,5,1–24.

7. Nayak, N., Prarthana, T., Joshi, R., Vaibhavi, S., & Swathi, S.(2023). Medical prescription recognition using machine learning: A survey.International Research Journal of Modernization in Engineering Technology and Science,5(4), 7279–7284.

8. Tariq, R. A., Vashisht, R., Sinha, A., & Scherbak, Y. (2024).Medication dispensing errors and prevention.USA:StatPearls Publishing.

9. Ramamurthy, K., Gumber, S., Abdelfattah, W.M. et al. Human AI trust modeling in cognitive systems via ensemble learning and advanced feature engineering. Discov Artif Intell 6, 366 (2026). https://doi.org/10.1007/s44163-026-01255-7

10. Philip, P. G. (2026). Artificial Intelligence–Driven Intelligent Project Management: an integrated framework for planning, scheduling and control in engineering and construction projects. Journal of Engineering and Artificial Intelligence, 02(02), 01–09. https://doi.org/10.64142/jeai.2.2.50

11. Chowdhury, W. A. (2025). Blockchain for Sustainable Supply Chain Management: Reducing Waste Through Transparent Resource Tracking. Journal of Procurement and Supply Chain Management, 4(2), 28–34. https://doi.org/10.58425/jpscm.v4i2.435

12. S. R. Lankala, M. R. Marri, A. Jain, G. G. Battu, U. Lakhina and S. Singla, "Optimal Financial Fraud Detection and Alerting Mechanism in Cloud Computing Using Deep Belief Network," 2025 International Conference on Emerging Trends in Networks and Computer Communications (ETNCC), Windhoek, Namibia, 2025, pp. 743-748, doi: 10.1109/ETNCC66224.2025.11299665.