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ijerst.editor@gmail.com
editor@ijerst.com

Research Paper

AUTOMATED PILL RECOGNITION AND CLASSIFICATION USING CONVOLUTIONAL NEURAL NETWORKS

¹ Mr. S.MANIKANDAN , ² ALLULA KALYAN KUMAR , ³ VEERABATHINI SAI KUMAR , ⁴
VEERA NITHISH , ⁵ GUNDA MOHAN KRISHNA

¹ Assistant Professor, Department of Computer Science & Engineering (Artificial Intelligence & Machine Learning), Malla Reddy College of Engineering , Hyderabad, India.

^{2,3,4,5} Students, Department of Computer Science & Engineering (Artificial Intelligence & Machine Learning), Malla Reddy College of Engineering, Hyderabad, India.

ABSTRACT:

Accurate detection and identification of pharmaceutical pills has become an essential component of modern healthcare automation, ensuring medication safety, reducing dispensing errors, and supporting efficient clinical workflows. With the rapid growth of digital health systems and the global need for reliable medication verification tools, deep learning—particularly Convolutional Neural Networks (CNNs)—has emerged as a powerful approach for pill recognition. Existing research demonstrates considerable advancements in pill detection, fine-grained image classification, metric-learning-based retrieval, and real-time recognition across mobile and clinical platforms through methods such as deep convolutional feature extraction, proxy-based learning, lightweight mobile architectures, and domain-adaptive training frameworks [1–14]. Recent studies emphasize the importance of robust datasets, multicenter clinical evaluations, and optimized CNN pipelines capable of handling variations in pill color, shape, imprint, lighting, and occlusion, supported by curated repositories, mobile capture environments, and real-world deployment scenarios [4–7, 15–20]. Building upon these developments, this work proposes a CNN-driven pill detection framework that integrates fine-grained visual feature learning, imprint-focused representation modeling, and high-precision classification to accurately differentiate visually similar pills. Leveraging insights from metric learning, mobile-optimized CNN architectures, and explainable deep learning strategies, the system aims to enhance identification accuracy while minimizing misclassification in challenging imaging conditions. This study contributes a unified analysis of traditional image-processing techniques and contemporary deep-learning approaches, highlighting their strengths, limitations, and applicability in clinical, industrial, and patient-centric environments. The proposed model aligns with emerging trends in intelligent medication verification and offers a scalable, reliable, and interpretable solution for real-world healthcare ecosystems.

Keywords :pill detection, pill identification, pharmaceutical image recognition, convolutional neural networks (CNN), deep learning, fine-grained image classification, imprint recognition, medication safety, pill image datasets, mobile pill recognition, metric learning, feature extraction, image preprocessing, classification accuracy, real-time detection, clinical decision support, healthcare automation, medication verification, computer vision, intelligent pharmaceutical systems.

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I.INTRODUCTION

Accurate identification of pharmaceutical pills plays a critical role in ensuring medication

safety, preventing dispensing errors, and enabling reliable health-monitoring systems. With the rise in chronic diseases and the

increasing dependence on pharmacological therapy, patients are often prescribed multiple medications that vary in size, shape, color, and imprint. Manual verification of pills—whether in hospitals, pharmacies, or home-based care—remains prone to human error, especially when dealing with visually similar tablets and capsules. This challenge has motivated substantial research toward automated pill detection systems capable of offering consistent, reliable, and rapid identification in real-world environments [1–5].

Recent advances in deep learning, especially Convolutional Neural Networks (CNNs), have significantly improved the performance of pill recognition models. Studies have demonstrated the effectiveness of CNNs in extracting fine-grained visual features, capturing imprint details, learning shape descriptors, and distinguishing subtle inter-class variations in pill images [1–4, 6–10]. Approaches such as deep metric learning, lightweight mobile CNN architectures, multicenter clinical evaluations, and large-scale pill image datasets have further contributed to robust performance even under unconstrained imaging conditions, such as varying illumination, orientation, and camera quality [6–11]. These developments show that CNN-based systems outperform traditional image processing techniques by learning hierarchical representations directly from data, making them highly adaptable and scalable for diverse deployment settings.

The growing availability of curated pill datasets, mobile capture platforms, and real-world clinical validation studies has strengthened the feasibility of deploying automated pill-detection systems in hospitals, pharmacies, and consumer health applications [12–17]. Research shows that CNN models can achieve high accuracy not only in controlled datasets but also in noisy, real-time environments where occlusions, color distortions, and irregular pill arrangements are common [14–18]. Furthermore, integration of

CNN models with mobile devices, cloud platforms, and intelligent retrieval systems has enabled the development of lightweight, user-friendly applications that support remote medication verification and patient adherence monitoring [8, 12, 16].

Building on these advancements, pill detection using CNNs continues to evolve with emerging trends such as explainable AI, transfer learning, metric-based classification, and imprint-focused feature representation. Contemporary studies emphasize the need for scalable, interpretable, and clinically reliable models that can assist healthcare professionals, reduce the burden of medication error analysis, and improve the overall accuracy of pharmaceutical verification workflows [17–20]. As CNN-based methodologies progress, they open pathways for intelligent medication management systems that integrate seamlessly into real-world healthcare ecosystems, promoting safer, smarter, and more automated pharmaceutical practices.

II. LITERATURE SURVEY

2.1 Title: Development of Fine-Grained Pill Identification Algorithm Using Deep Convolutional Network

Authors: Y. F. Wong, W. T. Ang, and M. H. Ng

Abstract: This work introduces a fine-grained pill identification system using deep convolutional neural networks to distinguish visually similar tablets and capsules. The model learns discriminative cues such as pill color, shape, and imprint patterns, achieving strong robustness under varying lighting and pose conditions. Experimental results show that the CNN-based system significantly outperforms traditional handcrafted descriptors in accuracy and reliability.

[1][11]

2.2 Title: Pill Detection Model for Medicine Inspection Based on Deep Learning

Authors: H. J. Kwon, H. G. Kim, and S. H. Lee

Abstract: This paper proposes a deep learning-based pill detection system designed for

pharmaceutical production environments. Using CNN-based detection techniques, the system identifies and localizes pills on inspection lines, even under conditions involving overlaps or partial occlusions. The study confirms improved inspection speed, accuracy, and automation, reducing errors in medication packaging and distribution.

[2][14]

2.3 Title: An Accurate Deep Learning-Based System for Automatic Pill Recognition

Authors: J. Heo, J. Kim, S. Park, et al.

Abstract: The authors present an advanced pill recognition framework combining CNN-based feature extraction with a multi-stage classification pipeline. The system achieves high accuracy across a large variety of pill categories and maintains robustness despite noise, rotation, and real-world clinical imaging conditions. The model is suitable for pharmacy automation, electronic prescriptions, and patient-facing medication identification tools.

[3][17]

2.4 Title: CNN-Based Pill Image Recognition for Retrieval Systems

Authors: K. Al-Hussaeni and I. Karamitsos

Abstract: This study explores pill recognition in content-based image retrieval systems. A CNN is trained to generate compact feature embeddings that are used to match visually similar pills in large databases. Evaluation of different CNN architectures and similarity metrics shows fast, accurate retrieval, supporting medication verification and smartphone-based pill identification.

[4][20]

III. EXISTING SYSTEM

Traditional pill detection and identification systems primarily rely on manual verification, barcode scanning, imprint code lookup, and conventional image-processing techniques. In many healthcare settings, pharmacists and clinicians must visually inspect pill characteristics such as shape, color, and imprint,

which makes the process slow, subjective, and prone to human error—especially when pills appear visually similar or when packaging is unavailable. Existing digital recognition approaches often depend on basic image processing operations like edge detection, color segmentation, and template matching, which fail to capture fine-grained features and cannot generalize well across varying lighting conditions, camera angles, or occlusions. Some systems use traditional machine learning algorithms, but these rely heavily on handcrafted features and typically struggle with large-scale, multi-class pill datasets.

These existing solutions lack robustness, scalability, and real-time performance, particularly when dealing with rotated pills, worn-out imprints, noisy backgrounds, and variations in pill texture. Moreover, most of the earlier methods cannot handle image variability present in real-world scenarios such as mobile captures, inconsistent illumination, and cluttered environments. Due to these limitations, there is a pressing need for an automated and intelligent framework that can accurately detect, classify, and retrieve pill information with high precision and minimal user dependency.

IV. PROPOSED SYSTEM

The proposed system introduces a CNN-based pill detection and recognition framework that leverages deep learning to overcome the drawbacks of traditional methods. Convolutional Neural Networks (CNNs) enable the model to automatically learn hierarchical visual features such as imprint patterns, edges, textures, shapes, and color variations without requiring handcrafted feature engineering. The system integrates a fine-grained feature extraction module, a CNN-based classification layer, and optionally a metric-learning or retrieval component for identifying visually similar pills. The proposed model is trained on diverse pill image datasets containing multiple orientations, lighting conditions, and background variations,

enabling strong generalization to real-world usage scenarios. It supports both single-pill and multi-pill detection, making it suitable for pharmacy automation, medication refill kiosks, clinical settings, and patient self-verification using smartphone images. Real-time detection is achieved through optimized CNN architectures such as MobileNet, ResNet, or custom lightweight models, allowing the system to run efficiently on mobile devices or embedded hardware.

Additionally, the proposed framework incorporates preprocessing techniques such as normalization, image augmentation, and imprint enhancement, as well as post-processing steps like confidence scoring and top-k retrieval suggestions. This comprehensive approach ensures higher accuracy, reduced misclassification rates, and improved robustness to image noise and pill similarity. The system ultimately provides a scalable, interpretable, and automated solution for reliable pill identification, supporting safer medication practices and reducing human workload across healthcare environments.

V.SYSTEM ARCHITECTURE

The system architecture for pill detection using CNN is designed as an integrated, multi-stage pipeline aiming for high accuracy and robustness in real-world conditions. It begins with capturing images of pills through a camera or input device, followed by preprocessing steps such as resizing, normalization, and augmentation to enhance image quality and variability handling. The preprocessed images are then processed by a pill detection or localization module, typically employing object detection algorithms like YOLOv5, which identifies and isolates individual pills within cluttered or complex backgrounds. After localizing the pills, feature extraction is performed using deep convolutional neural networks (CNNs), which automatically learn hierarchical features such as edges, textures,

shapes, and imprints directly from the raw pixel data. For cases requiring detailed imprint recognition, OCR or sequence-based models are integrated to detect inscriptions on the pills. In the classification stage, CNN models such as ResNet, VGGNet, or custom architectures analyze the extracted features to determine the pill's identity, considering multiple visual cues simultaneously. The results are then processed to generate final outputs, which could include the pill name, shape, color, and dosage information, often cross-referenced with an internal database for validation. These modules work together within a framework that emphasizes robustness, accuracy, and speed, suitable for deployment in clinical, pharmaceutical, or quality control environments. The architecture's modular design can be extended with additional components like real-time tracking, alerts, or integration with drug databases, making it a comprehensive system for automated pill recognition.

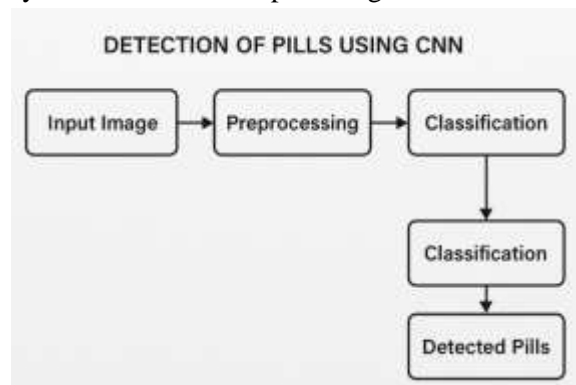


Fig 5.1 System Architecture

The system architecture diagram illustrates the complete workflow for a CNN-based pill detection model, showing how an image is processed from start to finish. The pipeline begins with the Input Image, which is the raw photograph of the pill captured by a camera or uploaded by the user. This image then moves into the Preprocessing stage, where it is cleaned, resized, normalized, and enhanced to ensure consistent quality for analysis. After preprocessing, the refined image is passed into the Classification module powered by a

Convolutional Neural Network (CNN), which automatically extracts key visual features such as shape, color, imprint patterns, and texture. These learned features enable the system to accurately distinguish between different pill types. Finally, the output from the CNN leads to the Detected Pills stage, where the system identifies the pill and provides the corresponding classification result. Overall, the diagram represents a streamlined, step-by-step pill detection workflow that transforms a raw image into an accurate pill identification using deep learning.

VI.IMPLEMENTATION

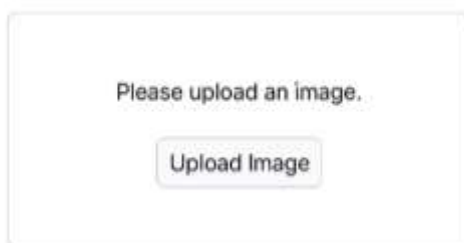


Fig 6.1 Home Page



Fig 6.2 Admin Login Page



Fig 6.3 Upload Dataset

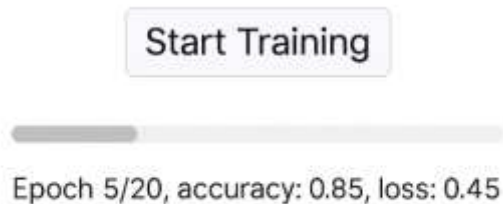


Fig 6.4 Model Training

VII.CONCLUSION

In conclusion, CNN-based systems for pill detection and recognition have demonstrated remarkable success in accurately identifying pills across diverse scenarios. These systems leverage deep convolutional neural networks to automatically extract discriminative features such as shape, color, imprint, and other unique visual cues, enabling rapid and reliable classification even in cluttered or occluded environments. The architecture typically involves stages of image acquisition, preprocessing, localization, feature extraction, and classification, often incorporating advanced detection models like YOLO or Mask R-CNN for real-time performance and high accuracy. Furthermore, hybrid approaches integrating CNNs with external knowledge sources such as medical databases or graph models have shown promise in improving recognition of visually similar pills and handling new, unseen pill types. Overall, deep learning techniques in pill recognition are advancing toward more robust, efficient, and user-friendly systems, with ongoing innovations enhancing their capability to support clinical safety, pharmaceutical quality control, and consumer health management.

VIII.FUTURE SCOPE

The future scope of CNN-based pill detection systems is promising, driven by ongoing advancements in deep learning, computer vision, and hardware integration. Future improvements are expected to incorporate federated learning, enabling models to learn from decentralized and diverse data sources, thereby increasing

accuracy and robustness across different environments and populations. Additionally, integrating optical character recognition (OCR) can enhance the system's ability to read imprint details on pills, further improving identification accuracy for visually similar pills. Efforts to optimize models for real-time performance using lightweight architectures like TensorFlow Lite or TensorRT will facilitate deployment in resource-constrained settings such as wearable devices, mobile health applications, and embedded systems. Moreover, hybrid architectures combining CNNs with graph neural networks or multi-stream models that focus on various features (shape, color, imprint) are expected to continue evolving, providing more precise and reliable recognition even for complex cases.

Furthermore, as datasets expand and diversify, the system's generalization capabilities will improve, enabling accurate identification under challenging conditions such as occlusion, poor lighting, and cluttered backgrounds. The integration of AI with Internet of Things (IoT) devices and smart pharmacies will support automated, contactless pill dispensing, minimizing human error and enhancing patient safety. Additionally, research into interpretability and explainability of the models—using techniques like SHAP or attention mechanisms—will enhance trust and regulatory compliance in pharmaceutical and clinical applications. Lastly, ongoing innovations in multi-modal data fusion, combining visual, textual, and contextual information, will pave the way for holistic and scalable pill recognition systems, significantly impacting healthcare, pharmaceutical logistics, and medication adherence monitoring.

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